Development of a Decision Making Model for the Assessment of Electricity Demand Side Management in the State of Kuwait

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ABSTRACT

Kuwait's per capita electrical energy consumption is among the largest in the world, reaching 13,663 kWh per person in 2011. The electricity demand in Kuwait is increasing, which requires additional investments in power generation. A particular challenge in Kuwait is the peak demand in summer, when extreme heat increases air conditioning loads. Peak demand reached 11,220 MW in 2011, with a fast growth rate averaging 5.6% over the last decade and a maximum production capacity of around 14,720 MW. It is not possible to cope with this demand simply by increasing generation capacity. Therefore, the only alternative available to Kuwait is to control electricity demand via demand-side management.

The main objective of this research is to assess and select the optimal demand-side management (DSM) technologies for buildings in the governmental sector (office, religious and school buildings) and to investigate the key factors in the evaluation process.

To achieve the research objective, a model was proposed using multi-criteria decision-making techniques to enable the forecasting and comparison of DSM alternatives that are suitable for buildings. The developed model includes environmental, economic, technical and social considerations.

The research methodology is based on three main phases. Phase 1: Data collection through a mail questionnaire that was sent to 42 experts for the identification of criteria and demand-side management alternatives. Phase 2: Screening and narrowing of the data collected in Phase 1 using a set of questionnaires, including the identification of potential DSM alternatives and criteria suitable for further analysis. This phase was performed through the Delphi process, taking into consideration the opinions of 28 experts. Phase 3: Use of Multi-criteria Decision Making (MCDM) techniques, namely the Analytic Hierarchy Process (AHP) and Fuzzy Analytic Hierarchy Process (FAHP), to evaluate and rank the identified DSM alternatives and criteria. This was done using pairwise comparisons of 17 experts to evaluate the criteria and alternatives for the buildings (office, religious and school).

The research showed that the experts identified six alternative technologies and five criteria for the selection and evaluation of governmental buildings (office, religious and school).

After performing the three phases of this research project, a set of criteria and alternatives were ranked based on the information gathered from every group of experts. It was found that reduction in consumption, capital cost and ease of implementation were the three most recommended criteria for the selection of DSM technologies in Kuwait government buildings while high efficiency lighting and programmable thermostats were identified as the most recommended DSM technologies for these buildings. An important aspect of this research is that unlike engineering approaches which sometimes depend on expensive test equipment or, often for building design, expensive computer modelling exercises, the proposed framework can be easily adopted by anyone without any significant financial cost.

The FAHP approach was also tested and its results compared with those of AHP. There was a slight difference between using AHP and FAHP in terms of ranking the criteria and alternatives but that the difference barely affects the ranking. It was found that the AHP provides a convenient MCDM approach for solving the complex problem of selecting the optimal DSM options for buildings.

The contributions of this thesis are the development of a novel framework for systematic selection and ranking of DSM technologies in different types of buildings using the Delphi method and AHP; the identification of the most important DSM technologies and criteria for their selection for three types of governmental buildings in Kuwait; and establishing that results from using AHP and FAHP for the selection of appropriate DSM measures in these buildings are almost identical, so use of AHP is likely to be sufficient in most building studies of this type.

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ABREVIATIONS

AHP	Analytic Hierarchy Process
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning
CO2	Carbon Dioxide
COMPASS	comprehensive market planning and analysis system
DA	Decision analysis
DM	Decision making
DSS	Decision support systems
DOE-2	Computer program for building energy simulation
DSM	Demand Side Management
DTLR	Department of Transport, Local Government and the Regions (UK)
ELECTRE	Elimination and Choice Expressing Reality
EIA	Energy Information Administration
EPRI	Electric Power Research Institute
EGAT	Electricity Generating Authority of Thailand's
FAHP	Fuzzy Analytic Hierarchy Process
GDP	Gross Domestic Products
GHG	Greenhouse Gas
GP	Goal programming
GWh	Gigawatt hour
HVAC	Heating, Ventilation and Air Conditioning
IEA	International Energy Agency
KD	Kuwaiti Dinar
KISR	Kuwait Institute of Scientific Research
kW	Kilowatt
kWh	Kilowatt hour
MADM	Multi attribute decision-making
MCDM	Multi Criteria Decision Making
MODM	Multi objective decision making
MOLP	Multiple Objective Linear Programming
MEW	Ministry Of Electricity and Water
MW	Megawatt (1000 kW)
PROMETHEE	Preference Ranking Organization methods for enrichment evaluation
SODM	single objective decision-making
TOU	Time of use
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
TFN	Triangle Fuzzy Number

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Chapter 1. *INTRODUCTION*

"A kilowatt-hour saved is just like a kilowatt-hour generated." (Lovins, 1985).

Energy resources are a fundamental ingredient of all economic systems (American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), 2003). Energy, in all its forms (thermal and electrical), is essential to modern societies, and the availability of reliable energy sources is the key to maintaining economic growth and living standards. It is a necessity for commerce, transportation, households and industrial requirements.

In many countries, electrical energy is the prime source of energy in the industrial, residential and commercial sectors due to its multiform nature and ease of application (Gellings & Chamberlin, 1993). Increasing electrical energy demand due to rapid economic growth, population increases and changes in living standards increase the pressure on the utilities responsible for supplying electricity to consumers in all sectors.

In most countries of the world, electricity demand is increasing, and more investments in power generation are needed. For example, the actual and expected peak electricity demand in Kuwait for the 1975-2025 period is shown in Figure 1.1 below.

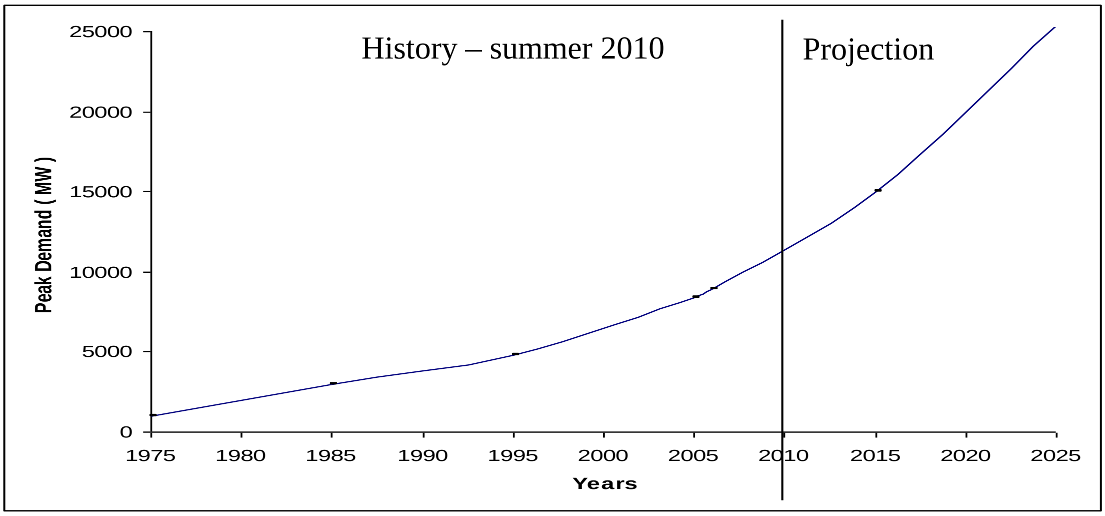


Figure 1.1: The actual and expected peak demand from 1975 to 2025 (MEW, 2010).

It is not possible to cope with this demand simply by increasing generation capacity. Thus, the only alternative available to Kuwait is to control electricity demand via demand-side measures. This is not only necessary to meet demand but can also reduce pollution, particularly carbon emissions, via increased power generation using fossil fuels. The carbon emissions estimates for Kuwait compared with those of selected countries can be seen in Table 1.1.

Table 1.1: Indicators of energy use and carbon emissions for selected countries, US Energy Information Association (2007)

Indicator	US	UK	Brazil	China	Kuwait
Per Capita Energy Use [GJ/person]	361.3	175.5	51.9	48.3	495.5
Carbon Emissions (Metric tons/Person)	5.50	2.62	0.5	0.99	8.42
Population (millions of persons)	293.03	60.27	184.10	1,298.85	2.26

This clearly indicates that increasing the power generation capacity of Kuwait will increase carbon emissions worldwide. Efforts to reduce consumption on the part of all energy-consuming sectors are therefore needed.

On its website, the Ministry of Electricity and Water (MEW) of Kuwait showed that on 13 June 2010, the peak power consumption reached 10,823 MW and hence reached very close to the installed capacity which is 11,200 MW. The temperature, meanwhile, increased to 49.5˚ C at around 14:00 local time in Kuwait City. The ministry of electricity and water asked its consumers to switch off air-conditioning units in unoccupied spaces, which is responsible for most of Kuwait’s power consumption, and thus minimize electricity consumption. In some cases, when the consumption level reached a critical point, and there was not enough production capacity, MEW was forced to resort to programmed cuts.

The problem of power shortage in Kuwait gets worse during the summer season, when electricity consumption by air conditioning units nearly reaches the generation capacity.

The per capita consumption of electricity in Kuwait reached 13,142 kWh in 2008. By international standards, this level is extremely high. The per capita consumption in Kuwait is almost four times higher than the world average[1] and 62 percent above the per capita consumption in United Kingdom. Even considering countries that have the same climate, Kuwait's per capita consumption is higher than Saudi Arabia's by 65 percent and higher than the United Arab Emirates' by 36 percent, as shown in Figure 1.2.

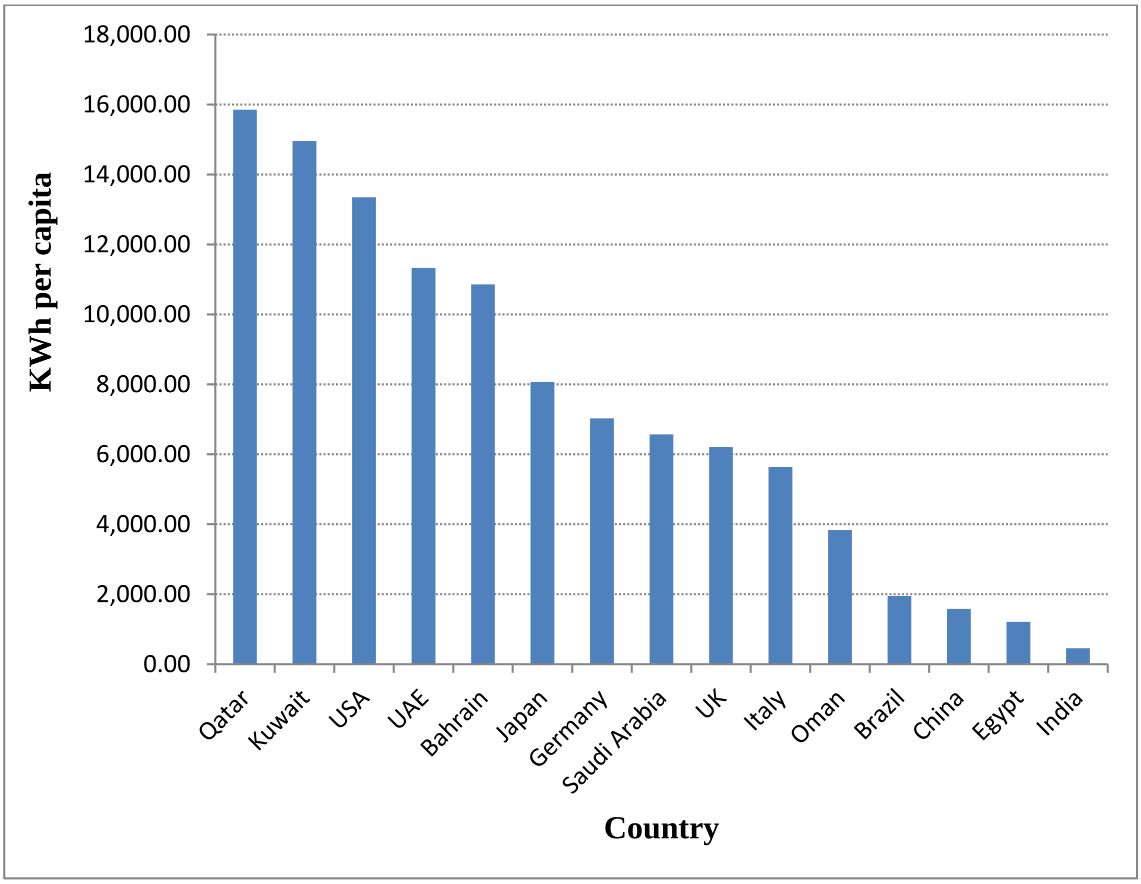


Figure 1.2: Per capita Electricity consumption for selected countries (NationMaster, 2012)

As demand for electricity is expected to grow in the future, very large financial investments will be required to bridge the gap between demand and supply, unless effective actions are taken to reduce consumption.

[1] Weighted Average world = 3,936.3 kWh per capita (NationMaster, 2012)

This thesis explores the assessment and selection of the optimal demand-side management technologies for buildings and investigates the key factors in the evaluation process. The aim is to establish systematic methods for the assessment and evaluation of DSM in Kuwait. The background of the research subject, the objectives and scope of this research and the structure of the thesis are explained in this opening chapter.

1.1 Research Background

The concepts of energy management are reviewed. Also, key problem areas in the research are pinpointed.

1.1.1 Concepts of energy management

The relationship between energy efficiency and energy conservation is poorly understood and frequently confused (Boardman, 2004). The two terms are often used interchangeably, but they mean different things. The following paragraph seeks to explore the differences between them.

During the oil crises of 1973, most countries became interested in reducing their energy consumption by minimizing their dependence on imported oil. The term energy conservation thus came to be used widely and to include many actions, such as encouraging consumers to insulate building, switch off lighting and adjust their thermostats.

Until the 1980s, the term energy conservation was widely used. However, the differences between energy conservation and energy efficiency can be illustrated via simple explanations. Energy efficiency takes advantage of advances in technology and system design to obtain the most productivity from every unit of energy and to eliminate energy waste.

Energy efficiency refers to the use of appliances that use less energy. An example is using compact fluorescent lamp, which uses less energy to obtain the same lighting level as that of incandescent lighting.

Energy conservation reduces energy consumption by changing human behaviour or changing the consumption load profile via installing new technologies. An example of changing human behaviour in order to save energy is turning off the lights when there is no need for them. An example of changing the consumption load profile is installing new technologies, such as programmable thermostats or time-of-use control.

Conservation measures are no-cost or relatively low-cost, but efficiency measures usually require a substantial investment, which is often cost-effective considering the reduced energy bills. Both energy conservation and efficiency measures help to reduce energy use. The efficiency of electrical appliances has improved significantly since the oil crises. However, people now have more appliances, and in some cases, these new appliances are larger or more energy-consuming, thus negating efficiency gains. Hence, improvements in energy efficiency may or may not lead to energy conservation.

Energy conservation also may not always provide benefits to the consumer. For example, during the oil crises, energy conservation measures in industrialized countries included power cuts and petrol rationing. Since the summer of 2006, Kuwait, one of the major oil-producing countries, has begun turning off electrical loads to limit peak electrical demand when the system reliability may be threatened. This energy management technique is called load shedding. Energy efficiency and energy conservation should bring real economic benefits to consumers in terms of lower energy costs, allowing them to maintain or improve their standard of living, and should therefore also benefit the economy as a whole.

The electric utility planning process has traditionally consisted of first estimating the demand for electricity and then finding the best set of supply options, i.e., hydro, nuclear, fossil fuel and other types of power generation, to meet the demand. Starting with the oil crises of 1973, this process became increasingly difficult. At that time, the emphasis was placed on using energy conservation and load management to satisfy customer and utility need and to join the national effort to conserve energy and save fuel.

From that time forward, energy planners began focusing on changing the traditional energy planning system and dealing with rapid demand increases by managing demand. The result has been a revolution in utility planning, which has been termed demand-side management (DSM).

1.1.2 Demand-side management

The term ‘demand-side management’ was first introduced in the US in the early 1980s to define utilities’ activities to manage or defer the consumer load profile. DSM is becoming a universally accepted means of reducing utility capacity needs and improving system operational performance (Rahman, 1996).

The broadest definition of DSM includes any utility activity designed to influence the pattern of customer electricity usage.

The Electric Power Research Institute (EPRI) in the USA has defined demand-side management as follows: “DSM is the planning, implementation and monitoring of utility activities designed to encourage consumers to modify their electricity consumption patterns, both with respect to the timing and level of electricity demand” (Gellings & Talukdar, 1985).

Demand-side management activities are those that involve actions on customer side, either directly caused or indirectly controlled by the utility. These activities include energy efficiency, strategic conservation, and load management (Gellings & Chamberlin, 1993).

Demand-side management could be viewed from two prospective, the utility perspective and the consumer perspective. The utility perspective includes any activities that take place on the utility side, i.e., improving the efficiency of a power plant, transformers, distribution lines, substations, etc., while the consumer perspective include any activities that take place on the customer side (i.e., end uses, appliances or measures).

From all the above definitions, it is clear that the concept of demand-side management includes the following:

- The concept of DSM was introduced specifically to refer to the electricity industry and has since been adopted by other utilities.
- DSM contains different activities on the part of consumers in different sectors.
- DSM can be categorized into consumer-side and utility-side actions.
- The main objective of DSM is to modify the consumers’ load pattern so as to satisfy the utility’s objectives.

DSM planning and implementation consists of a five-step process. The first step is identifying the load shape objectives. Steps two and three are identifying the alternatives and ranking the demand-side management programs. Step four is implementation, and step five is the monitoring and evaluation of the implemented programs. Figure 1.3 shows the DSM framework.

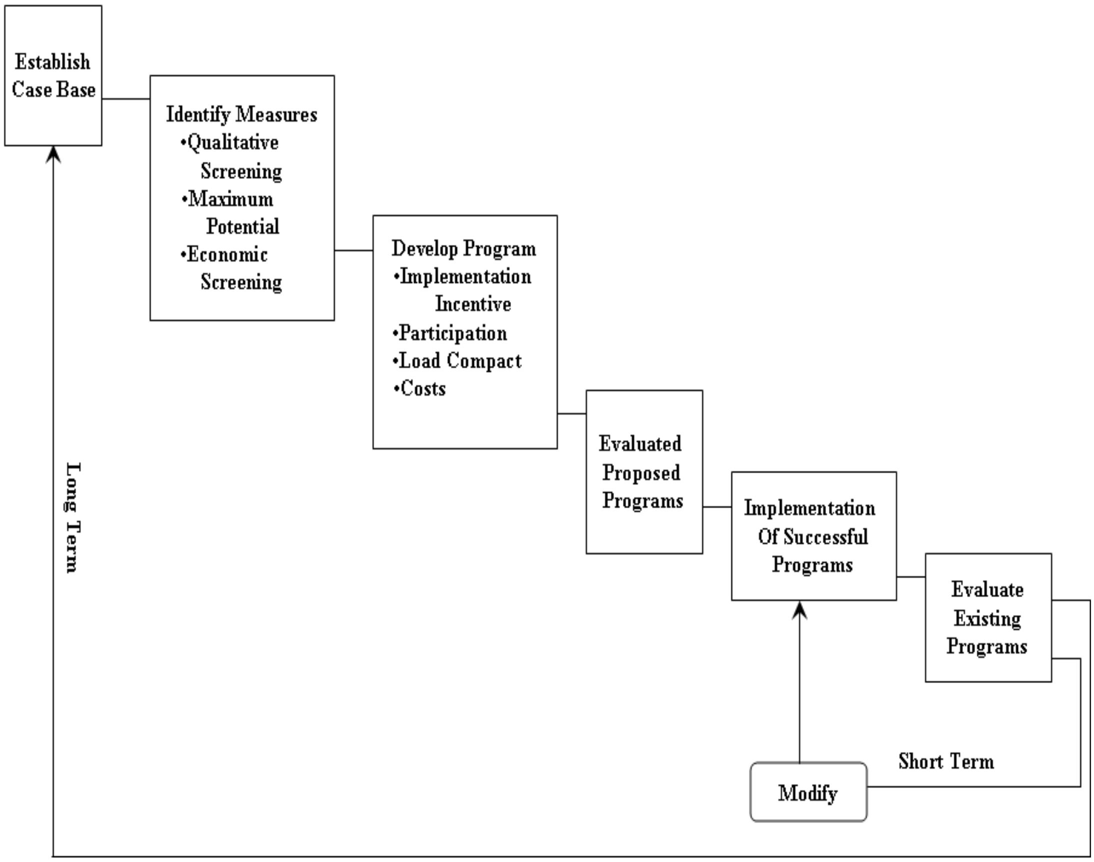


Figure 1.3 Demand-side management (DSM) framework (Gellings & Chamberlin., 1993).

1.2 Research Motivation

The modern energy structure is increasingly becoming complex, and many issues must be taken into account in energy planning, including energy security, demand and supply, environmental concerns, obligations to international agreements, socio-economic issues, sustainable development, greenhouse gas emissions, etc. (Andrews & Govil, 1995).

The screening and selection of demand-side management technologies is a complex problem, and often, the technologies do not meet expectations when selected for a specific building. The main problems can be attributed to insufficient selection due to not considering all attributes that could affect the selection of the optimal demand-side management technologies. The present work aims to help in eliminating these shortcomings in the decision making process and thus ensure the selection of the optimal demand-side management technologies in specific buildings.

To make decisions regarding which demand-side management technologies to use in buildings, decision makers are required to base their selections on several objectives, such as economic, societal, technical and environmental objectives.

A literature review reveals that much of the current decision-making work related to the selection of demand-side management technologies is based on a single criterion, such as an economic, technical or environmental criterion. For example, many research projects evaluate a specific DSM technology based on single a criterion. For example, Hill and Brown (1995) explore the cost-effectiveness of DSM programs in detail. Farag et al. (1999) provide a general assessment of the possible cost-effectiveness of DSM programs, which includes capital costs, customer perceptions, expected capacity costs avoided and operating efficiency gained.

Single-criterion decision making can be a problem because other factors or objectives, such as environmental, societal and technical concerns, may play an integral part in the acceptance of DSM technologies. It is this particular problem that the present study addresses via a decision-making tool that uses multiple criteria in choosing a DSM technology that satisfies various objectives.

Various studies have been developed to illustrate the potential applications of multi-criteria decision-making related to energy: studies for the assessment of energy alternatives compared to a certain criteria in order to make the options clearer (Goumas & Lygerou, 2000), studies for the evaluation of geothermal energy projects (Goumas et al., 1999), studies for the optimal selection of power plant sites (Barda et al., 1990) and studies aimed specifically at the evaluation of energy policies for small islands (Cavallaro, 1999). The multi-attribute decision-making (MADM) method is one of the most important technical support tools for strategic planning; it considers the relevant attributes in the selection of a suitable strategy with regard to the chosen attributes (Pan et al., 2000).

In Kuwait and at the national level for many developing countries, multi-criteria decision-making techniques have not been developed to support decision-making within the DSM selection process.

This study proposed a model using multi-criteria decision making techniques that provided a set of tools to help decision making in developing countries. This was done to more analytically address the process of selecting DSM technologies. The model enables the forecasting and comparison of DSM alternatives that are suitable for buildings. The developed model includes environmental, economic, technical and social considerations and has the potential to help in decision making regarding the assessment of DSM technologies in developing countries.

1.3 Research aim

This study aims to determine the most appropriate DSM measures that can be implemented in the governmental sector in Kuwait. Three type of buildings were selected for this research, namely office, school and religious buildings. This research investigated existing and new types of these building. The study emphasizes the priority of the various options regarding DSM technologies for the selected buildings in the governmental sector, which could be considered by the decision makers in the electric utility for the design and implementation of any future DSM program.

There has been growing interest in the area of decision-making models over the past two decades. This research aimed to develop a decision-making model capable of addressing numerous complex factors related to the selection of DSM technologies in Kuwait and less developed countries. Some of these factors are technical, economical, societal and environmental considerations. The complexity of the factors makes it difficult for decision makers in Kuwait to choose among alternatives for managing the problem, but a decision-making model can help solve this dilemma.

The decision-making process regarding the choice of alternative DSM technologies is multidimensional, being made up of a number of economic, technical, environmental, and social aspects. In this respect, multi-criteria analysis appears to be the most appropriate tool to use in understanding all the perspectives involved and supporting those concerned with the decision-making process by creating a set of relationships between the various alternatives. Thus, there is a need for a more objective, comprehensive and systematic method that utilizes multiple criteria and is not limited by single decision maker and a single decision criterion. Multi-criteria decision-making theory provides a set of formal techniques that are appropriate to this particular type of research.

1.4 Research Objectives

This research project aimed to develop a decision-making model capable of addressing complex multi-criteria factors related to selection of DSM technologies in Kuwait and less developed countries. The research adopts a systematic approach involving energy management stakeholders. Therefore, this study explores the issue of DSM and the evaluation process from various perspectives, including those of experts in energy management from academics and consultation companies, as well as contractors and building facility managers.

The main objectives of the study can be summarized via five explicit objectives:

1. To identify the potentially viable DSM alternatives and the viable criteria for use in the selection and evaluation processes for governmental buildings.

This objective is achieved by exploring the following research questions:

- What are the candidate DSM alternatives suitable for governmental buildings?
- What are the criteria/factors influencing the selection of DSM alternatives for use in governmental buildings?

2. To determine the most important criteria that influences the selection and evaluation of DSM alternatives for use in in governmental buildings.

This objective is achieved by exploring the following research question:

- What are the most preferred criteria/factors that influence the selection of DSM alternatives for use in governmental buildings?

3. To determine the most important DSM alternatives that can be considered for use in governmental buildings.

This objective is achieved by exploring the following research question:

- What are the most preferred DSM alternatives that are suitable for use in governmental buildings?

4. To design a model based on analytic hierarchy process (AHP) to analyse DSM alternatives and use it to identify the optimal DSM alternative for governmental buildings.

This objective is achieved by exploring the following research questions:

- Does the proposed model include multiple criteria of the research problem instead of a single criterion?
- What are the preferences regarding the DSM alternatives for each governmental building?

5. To employ the fuzzy analytic hierarchy process (FAHP) in order to compare the FAHP and AHP results.

This objective is achieved by exploring the following research question:

- What is the difference between the AHP and FAHP results?

1.5 Research Methodology

The research approach of this study is exploratory, which focuses on understanding the research context. The criteria identification, DSM alternatives identification, criteria and DSM screening and data collection of the research have been carried out in a qualitative manner, whereas the data analysis and validation steps have been carried out using quantitative techniques. Because the research aims to develop a multi-criteria decision-making model dealing with the selection of DSM technologies and generalize a concept of DSM assessment, an inductive approach has been adopted throughout this research. Questionnaire surveys and interviews are the techniques employed for data collection.

The core of the research methodology is based on three main phases:

- **Phase 1**: Data collection was performed through the literature review and questionnaires filled out by local experts in the energy management sector. The objective of this phase was to prepare a portfolio list of DSM alternatives and criteria measures.

- **Phase 2:** The data collected in Phase 1 were screened and narrowed using a set of questionnaires, including the identification of potential DSM alternatives and criteria suitable for further analysis. This phase was performed through the Delphi process, taking the experts' opinions into consideration.
- **Phase 3:** The DSM alternatives and criteria identified through the selected decision-making model were evaluated and ranked using two statistical processes: the analytic hierarchy process (AHP) and the fuzzy analytic hierarchy process (FAHP).

The approach provides a description of the instruments, the data collection process, and the type of analysis that will be carried out during each phase of the study.

Phase 1: This phase involves an in-depth interview/mail questionnaire completed by energy management experts in Kuwaiti organizations. The objective of this qualitative approach is to acquire richer data from energy experts and to gather the energy experts' knowledge of current and emerging demand-side management technologies suitable for governmental buildings, as well as to gather the experts' knowledge of critical criteria that influence the selection of demand-side management technologies in governmental buildings. Sample questions include the following:

- What demand-side management technologies are suitable for existing buildings (religious place/school/office)?
- What are the criteria to be considered when selecting demand-side management technologies for existing buildings (religious place/school/ office)?
- What demand-side management technologies are suitable for new buildings (religious place/school/office), including emerging technologies?
- What are the criteria to be considered when selecting demand-side management technologies for new buildings (religious place/school/office)?

The acquisition of this set of data enables the researcher to construct a more efficient instrument for use in phase two. The data collected from phase one will be combined with the comprehensive literature review to provide a more robust list of criteria and alternatives for the second phase, which involves the use of the Delphi method.

Phase 2: This phase involves the use of the Delphi method; the participating experts will respond to a series of questionnaires to achieve the objective of this phase, which is the identification of the criteria that influence the selection of demand-side management technologies in buildings and the identification of DSM alternatives.

The Delphi method is a method for structuring communications that allows a group of individuals, as a whole, to effectively deal with complex problems (Linstone & Turoff, 1975). The Delphi method structures communications via the following:

- Providing a feedback mechanism about individual contributions to a group.
- An assessment of the group's viewpoint and differing views.
- An opportunity for individuals to revise their views.
- The anonymity of the individual responses of participants.

Phase 3: This phase involved a pair-wise comparison questionnaire to quantify the experts' judgments of criteria and alternatives. This phase will lead to the development of a model based on the analytic hierarchy process (AHP) method in order to analyse the data collected from the three instruments defined in Section 1.5. The procedure for the AHP is described in detail in Chapter 4.

The three phases of the study will help to address the research objectives. Each phase of the study will extract essential data to assist in the development of the instrument of the subsequent phase.

The chart in Figure 1.4 shows the schematic approach for the entire study.

The study will target three types of governmental buildings, religious buildings, schools and office buildings. The main reason for selecting these three types of governmental buildings is that among all Kuwaiti governmental buildings, they consume a large portion of the total electricity.

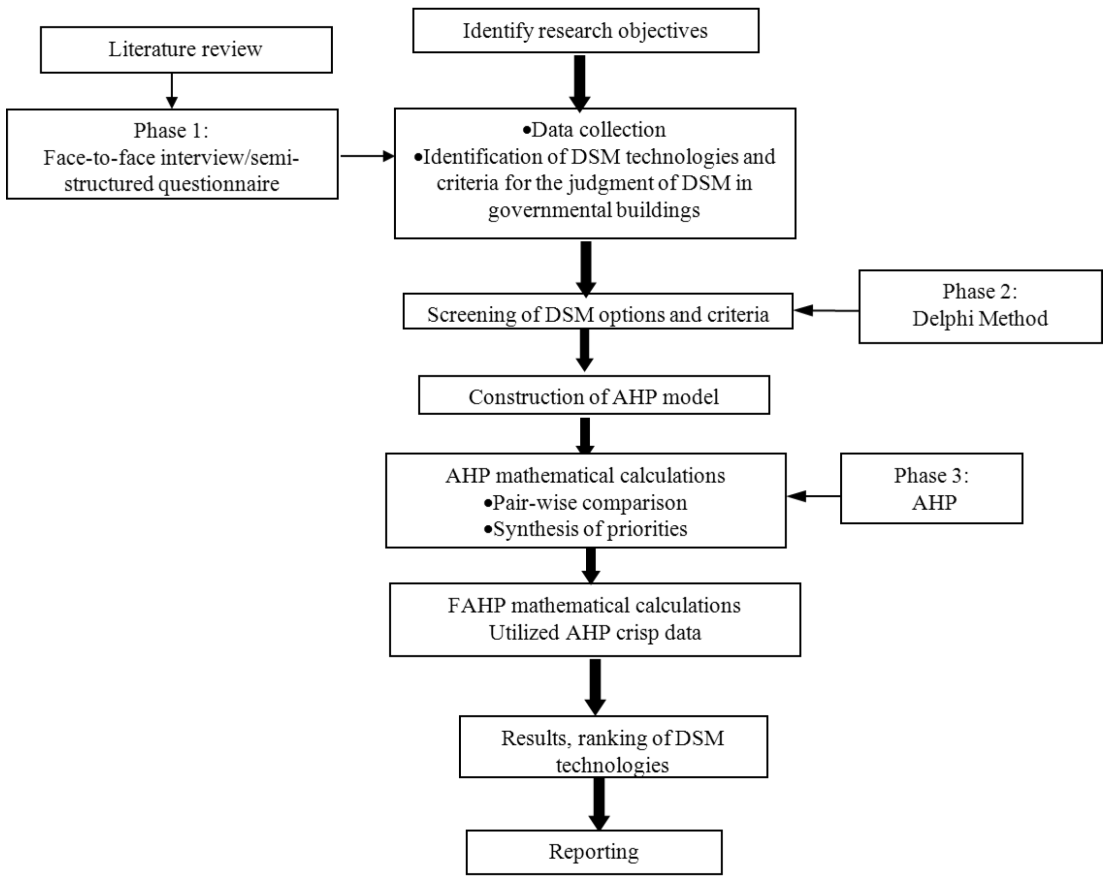


Figure 1.4 Research Plan

1.6 Limitations of the Study

Due to the amount of effort and time required for the implementation of this research, especially the development of the multi-criteria decision-making (MCDM) process and the data collection for the potential application of DSM, the scope of this research was limited to the development of an MCDM model for the governmental sector. Further limitations of the study are elaborated upon in Chapter 7.

1.7 Organization of the thesis

This research examined the potential application of DSM in governmental buildings in Kuwait, with an emphasis on the evaluation and ranking of DSM technologies. The research project is divided into seven chapters, as described below:

- In the first chapter, the objectives, motivation and limitations of this research are presented. The rationale behind selecting governmental buildings and the research methodology are also presented.
- Chapter 2 provides an overview of the energy situation and electricity demand in Kuwait, as well as the environmental factors affecting this demand. The development of energy consumption and peak demand are described, as well as the need for a strategic DSM approach.
- Chapter 3 provides the background literature review for the research. It reviews the concept and benefits of DSM and its correlation with integrated resource planning. This chapter also covers the assessment methods for DSM, including data collection, multi-criteria decision making and the analytical hierarchy process (AHP).
- Chapter 4 describes the methodology of the research. The framework of the research was based on theoretical foundations, problem identification, the study approach, and the selection of a decision-making model. The research instruments, the recruitment of experts, the justification of the research methodology and the research contribution are also described in this chapter.
- Chapter 5 describes the Delphi techniques of data collection and the Delphi questionnaire rounds, the performance of Delphi groups, screening for criteria and alternatives and the analytic hierarchy process model.
- Chapter 6 describes the results of AHP and fuzzy AHP, including relative criteria weights, relative DSM alternative weights and a comparison of AHP and FAHP results.
- Chapter 7 includes a summary of the key findings of the study, the study conclusions and recommendations for future work.

Chapter 2. *CHARACTERISTICS OF ELECTRICITY DEMAND IN KUWAIT*

2.1 Introduction

Electricity plays a crucial role in the development of modern society. The electricity supply in Kuwait is owned and managed by the Ministry of Electricity and Water (MEW). In the MEW, the Department of Electricity is responsible for the generation, transmission, and distribution of electricity, and it sells electricity directly to customers in all sectors, i.e., residential, commercial, governmental, industrial, and agricultural.

From 1995 to 2010, the per capita electricity consumption in Kuwait increased from 11,769 kWh to 14,860 kWh, making it the eighth largest per capita energy consumer in the world. However, peak electricity demand has increased much faster by around three fold since 1995 (NationMaster, 2010).

This chapter presents an overview of how electricity is used in Kuwait, how electrical demand is evolving over time, and how this demand is closely correlated to weather conditions. The indicators of energy consumption and the need for a strategic approach to promote and implement DSM programs are also discussed in this chapter.

2.1.1 Climate Characteristics in Kuwait

The climate in Kuwait, as in most of the countries in the Arabian Gulf region, is characterized as hot and arid, with long summer months extending roughly from April to November. The temperature in summer may exceed 50˚C (122˚F). In summer, the average daily high temperature ranges from 42 to 46°C (107.6 to 114.8°F); the highest ever temperature recorded in Kuwait was 53.5°C (128.3°F), which occurred at Kuwait International Airport on August 3, 2011. Between November and April, the winter months are milder than the summer (8 to 19 ˚ C), with cool and sometimes cold nights, warm sunny days and limited rainfall. The weather is generally dry. However, the humidity is higher in the coastal region of the country.

The hot weather of summer has a large influence on energy consumption and peak demand due to the extensive use of air-conditioning (A/C) systems.

Figure 2.1 shows the monthly average maximum and minimum temperatures for the year 2010 (MEW, 2010).

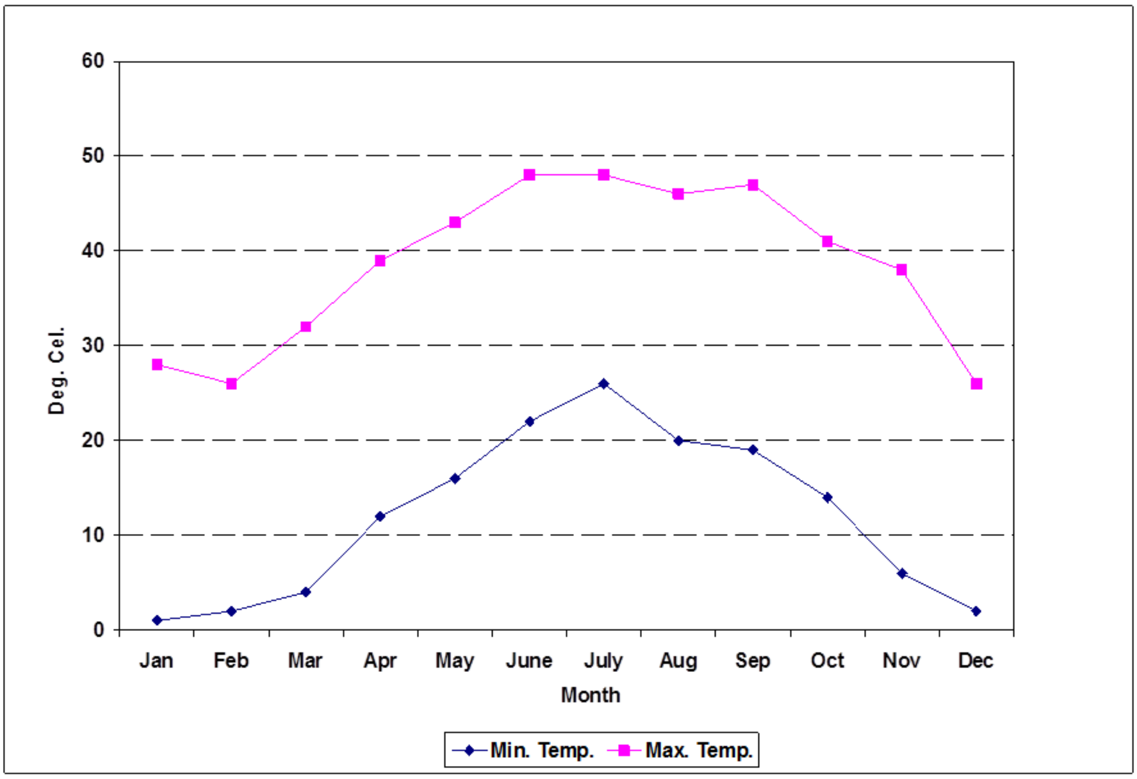


Figure 2.1 Kuwait Maximum and Minimum Temperatures Recorded in 2010

In its energy conservation programme code of practice guide, the Ministry of Electricity and Water (MEW, 1999b) states that air conditioning installations utilise 60 to 70 percentage of all electricity. To satisfy the continuous growth in demand, the only solution for the MEW is to build new power plants.

2.2 Pattern of Electricity Demand in Kuwait

In Kuwait, as in many developing countries, the rapidly growing economy and urbanisation are associated with a significant increase in building construction and energy demand (mostly in the form of electricity).

2.2.1 Installed Capacity and Generated Energy

To cope with the rapid and increasing electricity demand in Kuwait, the capacity of power plants in Kuwait has been increased from 9,189 MW in 2000 to 12,399 MW in 2010, with an average annual growth rate of approximately 3.1%. During the same period, the amount of energy generated grew rapidly from 32,323 GWh to approximately 61,660 GWh, with an average annual growth rate of 6.7% (see Table 2.1 and Figure 2.2).

Electrical power is generated by six power plants, in which mainly steam and gas turbines that burn fossil fuel (oil and natural gas) are used. Based on the MEW data from 2010, about 77% (8,970 MW) of the installed capacity is produced by steam turbines and 23% (3,429 MW) is from gas turbines.

Table 2.1 Development of Installed Capacity and Generated Energy in Kuwait

Year	Installed Capacity (MW)	Growth Rate (%)	Generated Energy (GWh)	Growth Rate (%)	Exported Energy[1] (GWh)
2000	9,189		32,323		27,463
2001	9,189	0.00%	34,299	6.11%	29,273
2002	9,189	0.00%	36,362	6.01%	31,053
2003	9,189	0.00%	38,577	6.09%	33,086
2004	9,689	5.44%	41,257	6.95%	35,632
2005	10,189	5.16%	43,734	6.00%	37,906
2006	10,229	0.39%	47,605	8.85%	41,416
2007	10,377	1.45%	48,761	2.43%	42,422
2008	11,082	6.79%	53,476	9.67%	46,524
2009	11,736	5.90%	58,011	8.48%	50,470
2010	12,399	5.65%	**61,660**	6.29%	53,644
AVG		3.1%		6.67%	

Source: MEW, Statistical Year Book, 2010

1. Exported energy = Generated energy - Consumption in power plants

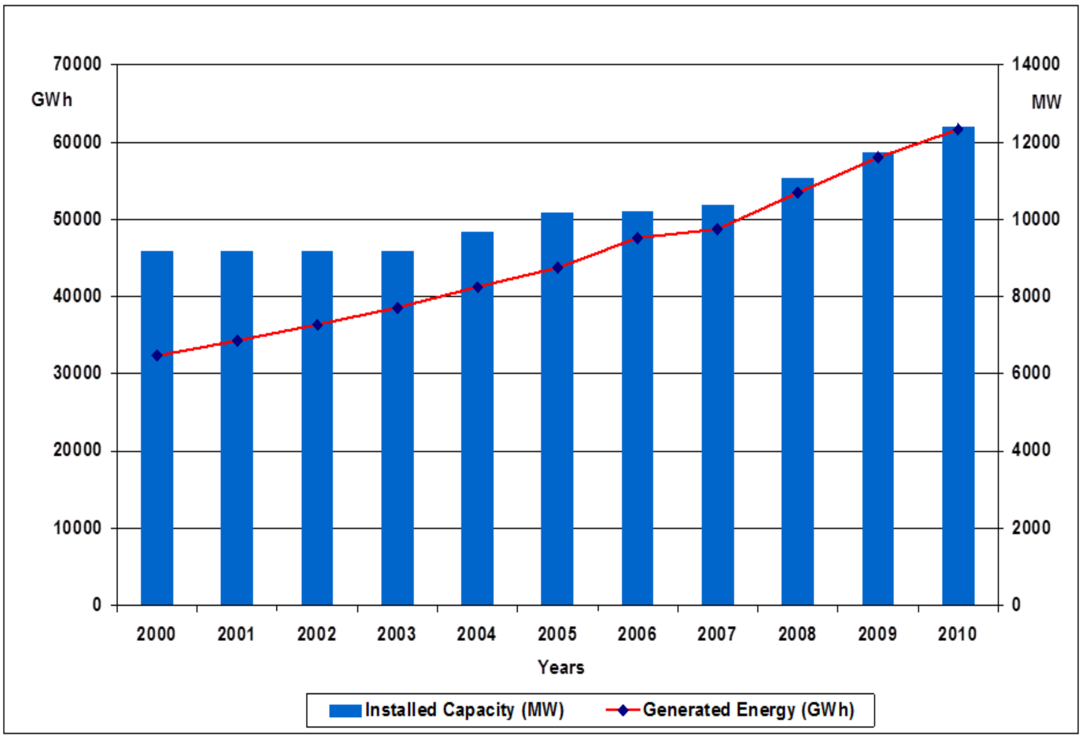


Figure 2.2 Development of Installed Capacity and Generated Energy, (MEW, 2010).

2.2.2 Peak Demand and Energy Consumption

From 2000 to 2010 the peak demand in Kuwait almost doubled, reaching 12,520 MW in 2010. The growth rate of peak demand from 2000 to 2010 was 6.9% (See Table 2.2). In contrast, the growth rate of the installed capacity was only 3.1%, as shown in Table 2.1, creating a complicated power supply situation. This was clear in 2006 and 2010, when Kuwait experienced major electricity supply crises triggered by rapid peak load growth due to the extensive use of air conditioning systems in very hot weather conditions. In 2006, the peak demand reached 8,900 MW, and the ambient temperature reached 49°C.

The development of peak demand during 2008 is illustrated in Figure 2.3. The summer peak, which occurred in July, reached 9,710 MW, approximately double the peak demand in wintertime. The monthly average maximum temperature is illustrated in Figure 2.4 below, showing the close correlation between its variation and peak load.

The demand profile on the day of the system peak is shown in Figure 2.3. The peak demand occurred on July, 27 from 2:30 - 3:30 pm and at a maximum temperature of 50ºC. It is clear from the curve that the minimum demand occurs from 6:00 to 8:00 am, when the surrounding temperature is relatively low (20-26ºC). These patterns are typical for all days during the summer period. The difference between the maximum demand (9,710 MW) and the minimum demand (7,200 MW) is approximately 2,500 MW, which represent 25.75% and 21.48% of the peak demand and installed capacity, respectively. The large gap between the maximum and minimum demand provides an indicator of the opportunity for demand management achievements.

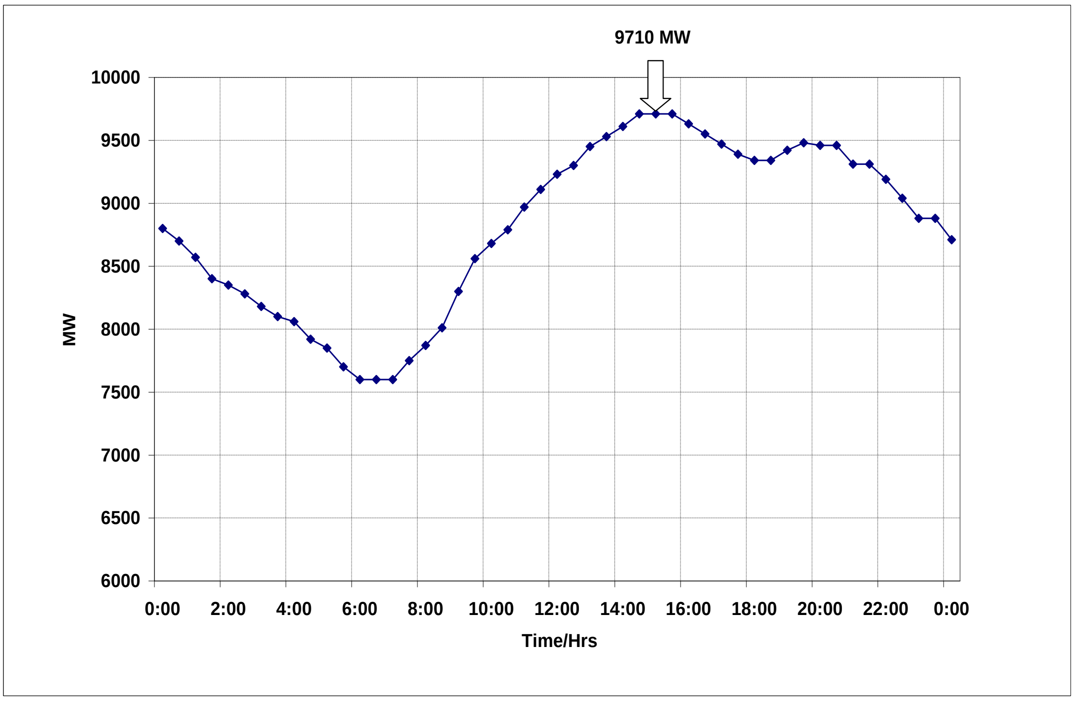


Figure 2.3 The Summer Peak Day System Load Profile in Kuwait for 2008.

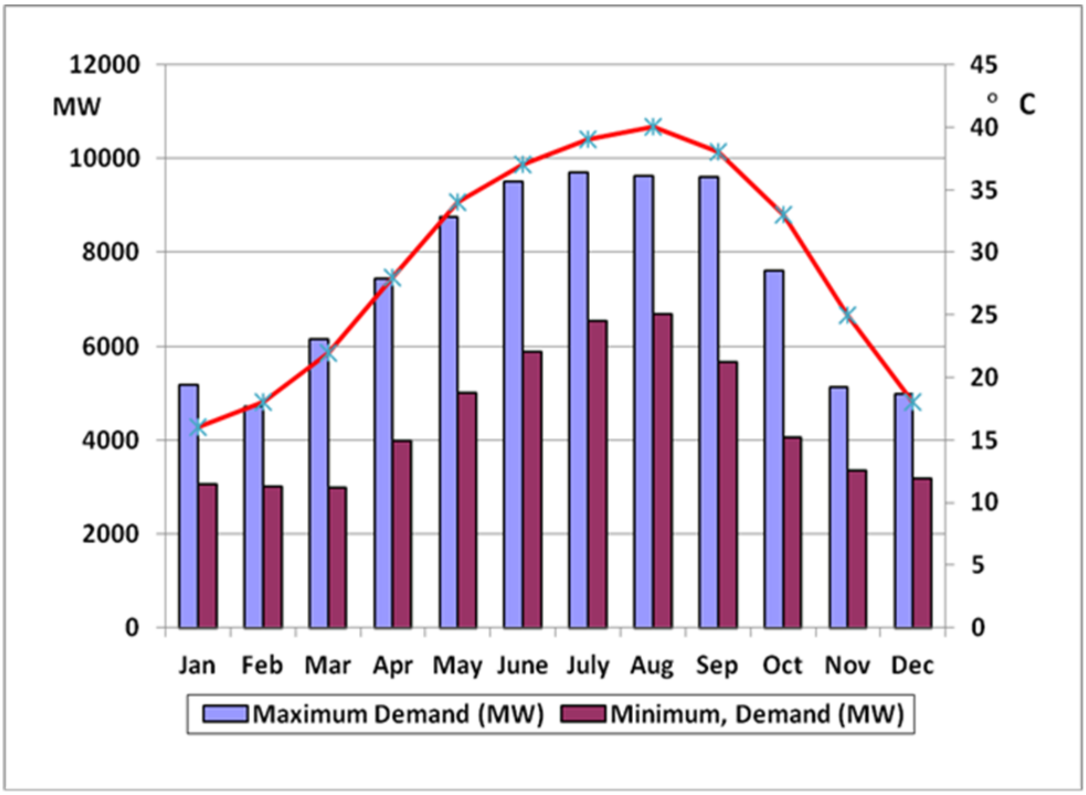


Figure 2.4 Monthly Maximum and Minimum Electricity Demand (columns) and Monthly Average Temperatures (line, right hand axis) (MEW, 2010).

The amount of energy exported to the grid (generated energy minus the energy consumed in power plants) is shown in Figure 2.5. By deducting the transmission and distribution (T & D) losses, which are estimated at 12% (MEW, 2010), the end-use energy consumption is estimated to be 47,207 GWh in 2010. The distribution of this energy by sector is shown in the pie chart in Figure 2.6. This distribution is based on the estimates published by Hajiah in 2003. The residential sector has the largest share of electricity consumption (64%), followed by the industrial (18%), governmental (10%), and commercial (8%) sectors.

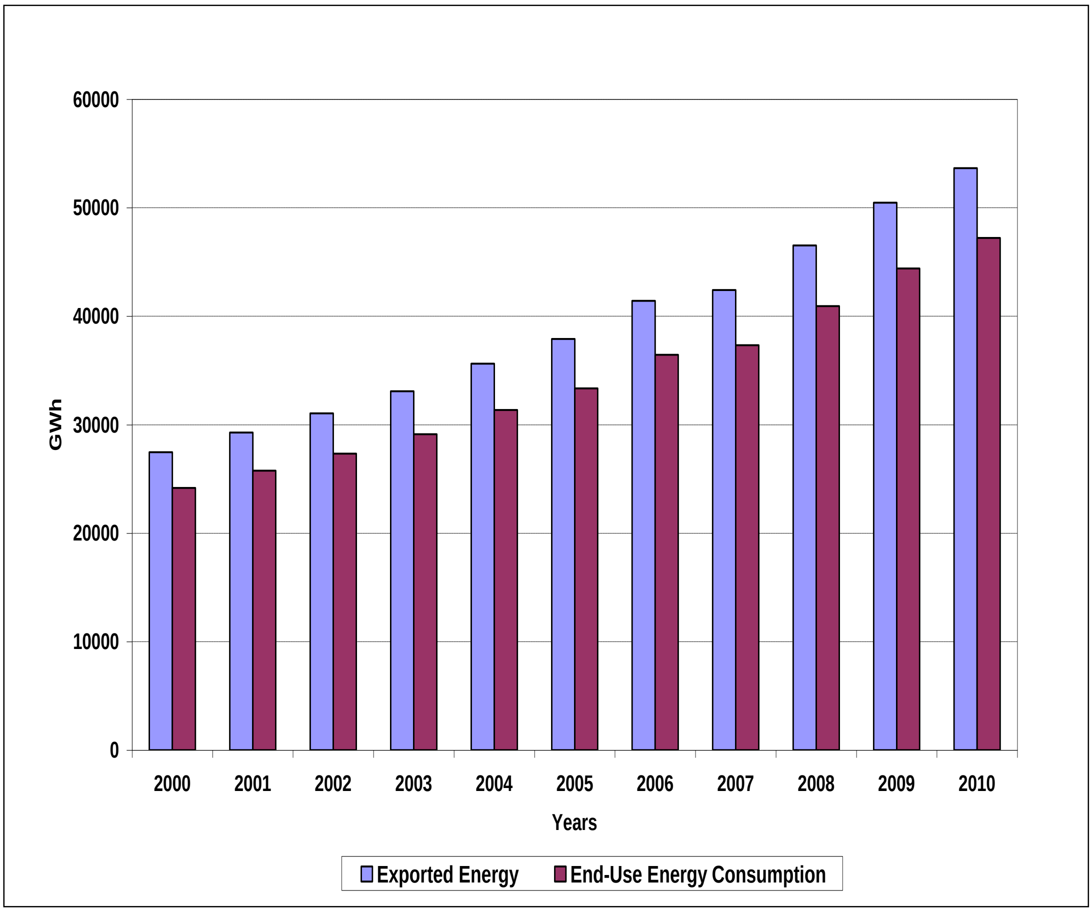


Figure 2.5 Electricity fed into grid, and end use consumption (MEW, 2010).

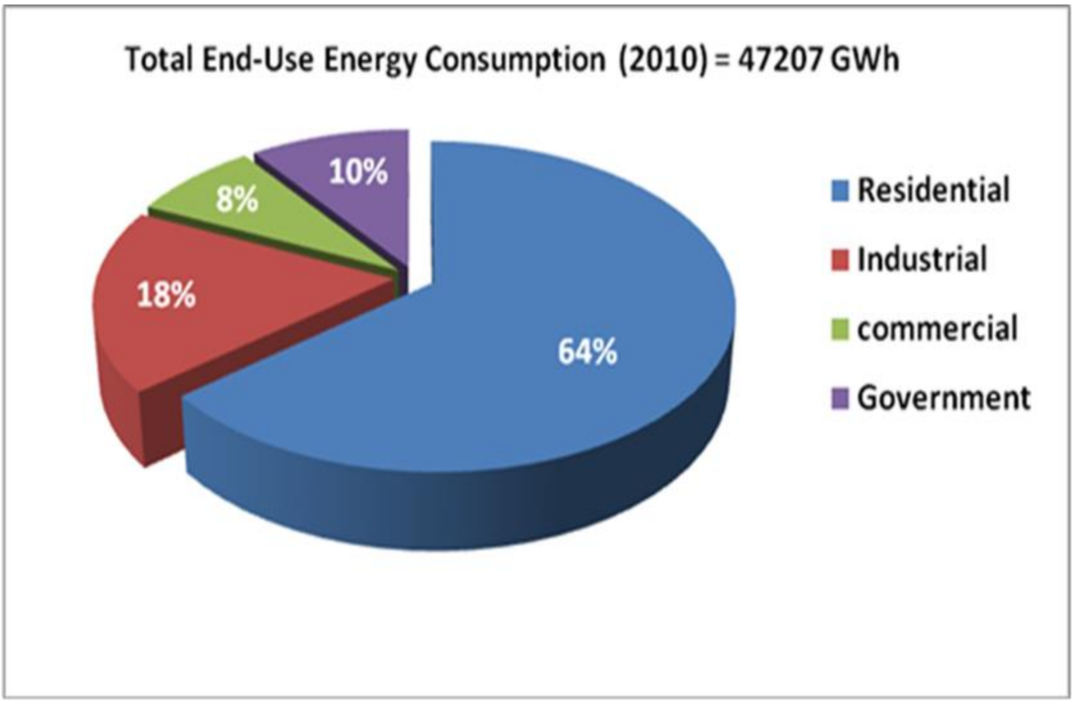


Figure 2.6 Distribution of End-Use Energy Consumption by Sector (MEW, 2010)

Table 2.2 Electricity Demand in Kuwait (2000 – 2010)

Year	Peak Load (MW)	Growth of Peak Load	Increase in Peak Load (MW)	Exported Energy[1] (GWh)	End-Use Elec. Consumption[2] (GWh)	Growth of End-Use Consum.(%)	Popul.	Growth of	Growth of GDP (%)
2000	6,450			27,463	24,167		2,231,908		
2001	6,750	4.7%	300	29,273	25,760	6.59%	2,309,102	3.46%	0.70%
2002	7,250	7.4%	500	31,053	27,327	6.08%	2,419,928	4.80%	2.80%
2003	7,480	3.2%	230	33,086	29,116	6.55%	2,546,684	5.24%	17.40%
2004	7,750	3.6%	270	35,632	31,356	7.70%	2,753,656	8.13%	11.20%
2005	8,400	8.4%	650	37,906	33,357	6.38%	2,991,189	8.63%	10.40%
2006	8,900	6.0%	500	41,416	36,446	9.26%	3,182,960	6.41%	5.30%
2007	9,070	1.9%	170	42,422	37,331	2.43%	3,399,637	6.81%	4.50%
2008	9,710	7.1%	640	46,524	40,941	9.67%	3,441,813	1.24%	5.50%
2009	11,385	17.3%	1,675	50,470	44,414	8.48%	3,486,557	1.30%	-4.80%
2010	12,520	10.0%	1,135	53,644	47,207	6.29%	3,610,000	3.54%	2.30%
AVG		**6.9%**	**607.00**			**6.9%**		**5.0%**	**5.53%**

Source: MEW, Statistical Year Book, 2010.

1. Exported energy = Generated energy - Consumption in power plants, 2. Final energy consumption = Exported energy - Network T. & D. losses (12%) , GR = Growth Rate,

GDP = Growth Domestic Product

2.3 Economic and Demand Growth

Kuwait, with a population of around 3.6 million people, has experienced remarkable economic development since 1946, when Kuwait exported its first cargo of crude oil.

Currently, Kuwait has proven crude oil reserves of 104 billion barrels, estimated to be 10% of the world's reserves (US Energy Information Administration (EIA, 2013)). The state has five power stations and a total power generation capacity of about 12.4 GW. In 2000, a new 2400 MW steam power plant that used fossil fuel (oil and natural gas) was commissioned that cost \$2.2 billion for construction only, not including operation and maintenance costs. In 2011, Kuwait provided funds for the construction of the Al-Zour North power plant, one of the country's largest projects to boost electricity supplies, which could cost an estimated KD750 million (\$2.7 billion). It is worth mentioning that Kuwait's oil industry accounts for 80% of governmental revenue. Petroleum and petrochemicals account for nearly half of GDP and 95% of export revenues.

During the past few years, the country witnessed major economic changes and events. Prior to the global financial crisis, most sectors in Kuwait were registering strong growth, especially the real estate, banking and investment sectors. From 2000 to 2008, Kuwait's real average annual economic growth rate was 6.4 percent, about three times higher than the rate in developed countries; at the same time, electric energy consumption (in the form of energy exported to the grid) grew 6.82 percent annually.

Recent data indicate that Kuwait has a GDP (Purchasing Power Parity) of US \$167.9 billion and a per capita income of US \$81,800, making it the fifth richest country in the world per capita. While economic growth improves living standards and encourages industrialization, it also increases the demand for new goods and services by improving consumers' purchasing power and leads to increases in electricity consumption.

In the summer of 2006, the Kuwaiti government encountered problems when power consumption peaked at 8,900 MW and power availability was reduced to 9,200 MW. August and September were the critical months, then temperatures decreased in October. A successful energy conservation campaign based on media awareness was launched in March of 2007 to cope with the critical summer of 2007. The results were amazing and reduced the annual increase in peak demand to 1.9% (2006 to 2007), while the average in the last ten years was 6.9%. The plan was for the energy conservation campaign to be implemented for four years, but due to political reasons, the campaign was stopped.

After three years, in the summer of 2010, the Kuwaiti government received a second alarm signal when power consumption peaked at 10,823 MW, dangerously close to the maximum available capacity of 11,200 MW, according to figures on the MEW website (MEW, 2010).

The slow implementation of development plans, as well as a lack of feedstock or any strategic plan for energy conservation, has created limitations in power supply during summers. Kuwait is now frequently experiencing shortages in electricity supply shortage. In the past decade, the development of Kuwait’s electric power sector has stalled due to political factors, despite consistent annual demand growth of about 7%, as mentioned in Table 2.2. Only one power plant was commissioned during that time, creating a suitable reserve margin after the shortage beginning in 2006.

Figure 2.7 shows the development of population, energy consumption and economic growth during the last decade. It is clear from the figure that during these years, peak demand and final (end-use) energy consumption have grown faster than the economy. This means that Kuwait’s energy and environmental trends are leading to serious problems.

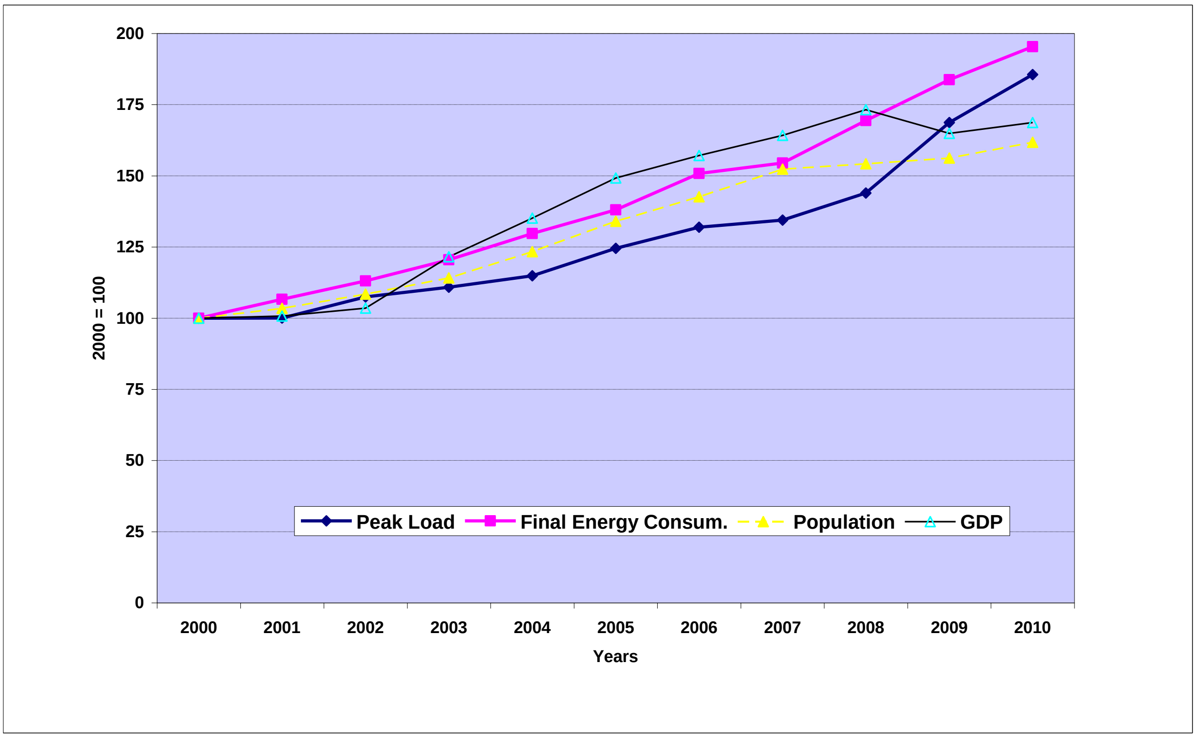


Figure 2.7 Development of Peak Demand, Energy Consumption, Population and GDP in Kuwait (2000-2010)

2.4 Strategic Approach to DSM

Measures for energy conservation in buildings have been implemented in Kuwait since 1983, when the Ministry of Electricity and Water (MEW) published a well-defined code of energy conservation practices (MEW, 1983). However, the code has not been updated to include the development of new technologies.

The realizable potential of the energy conservation program was estimated to amount to an approximately 25% reduction in the annual rate peak load growth and a 12% reduction in the rate of annual electrical energy production growth on the part of the utility. This reduction was estimated to amount to around 1600 MW of installed generation capacity and KD 800 million ($2,640 million) in capital cost savings by the turn of the century (Kellow, 1989).

With no up-to-date energy conservation program in Kuwait, poor practices exist within the built environment from an energy-efficiency point of view. Various case studies highlight the existence of such gaps and justify the urgent need for DSM techniques to ensure that the use of energy in large buildings is optimized. (AL-Hadban, 2005).

At present, buildings in Kuwait consume excessive amounts of electricity due to the absence of an updated code that includes high-efficiency measures and a clear framework for demand-side management programs in buildings.

In light of the above-mentioned indicators associated with electricity demand in Kuwait, it is clear that the current levels of electricity consumption indicate extravagant use of energy. These are compounded by the following main issues:

1. **An inefficient billing system**

A lack of bills being issued and a lack of bill-collecting procedures encourage irrational consumption. Very cheap electricity prices, which are set at a flat rate of only 2 Fils (≈ 0.4 UK Pence ≈ 0.7 US¢) per kWh and are equivalent to approximately 15% of the actual cost of generation, are also partly to blame. Kuwait has some of the lowest electricity tariffs in the world, and the Kuwaiti government should reduce subsidies in order to reduce national energy consumption. The increase in electricity consumption per capita reflects the extent of the luxury and abundance enjoyed by the people.

2. **Lack of demand-side management programs and policies**.

Under such conditions, it is important to emphasize that any DSM programme will be more attractive to the government (or the MEW) than to consumers. Demand-side management strategies and policies formulation is mandatory in order to provide electricity services in a reliable way. Electricity DSM is one of the fundamental solutions that will allow Kuwait to meet its growing demand and defer the construction of new power plants.

The objectives of the DSM programmes must include the following:

- Implementing energy efficiency and load management programs to maximize the benefits for consumers and the country.
- Increase awareness program and actively promoting energy conservation among electricity consumers.

- Stimulating local manufacturers and suppliers to produce or import energy-efficient appliances.

It is essential to devise and enforce demand-side management plans in Kuwait and less-developed countries in order to keep up with annual growth and meet the sustainable development requirements. Adopting demand-side management strategies is not limited to technology transfer and acquisition. The screening and selection of optimal DSM technologies will help energy decision makers in adopting such strategies in a systematic and confidence manner.

2.5 Conclusions

The weather in Kuwait is hot and dry in the interior areas and hot and humid in the coastal areas. This sort of harsh climate makes air conditioning systems a requirement in every building. Urban development and the growing economy in Kuwait have led to a significant increase in building construction and energy use. Meanwhile, energy efficiency indicators have shown that energy is often used irrationally. Two of the main reasons for the high per capita electricity consumption and non-efficient use of energy are the low price of electricity and a lack of awareness. DSM programmes are an essential strategic approach to saving energy. This is in contrast to traditional planning, which depends on the construction of new power plants to keep up with rapidly growing demand.

Chapter 3. *LITERATURE REVIEW*

3.1 Introduction

This chapter presents the research context of Demand Side Management (DSM) and covers studies related to utilising Integrated Resource Planning (IRP), DSM strategies, the selection, potential implementation and evaluation of its options.

In order to establish an up-to-date base knowledge on DSM evaluation process, a general review of the DSM concept and its benefits are presented in this chapter. As the chapter engages with the research context of DSM in buildings, the first part provides a background of the development of DSM and its definitions as well as a review of DSM assessment methods. The key DSM technologies of buildings are then introduced and their latest developments briefly addressed. After reviewing the potential benefits of the DSM technologies, the chapter identifies the gaps in the current evaluation and assessment of DSM technologies in building research that needs to be considered more seriously. The International Energy Agency (IEA) emphasizes the need to improve public and private decision-making frameworks and considers it as one of the IEA eight necessary conditions for improving energy efficiency (Jollands et al., 2010). In practice, a wide range of well-proven DSM technologies could be applied in any sector or end-use. An appropriate selection of these technologies, however, is a difficult task which is subject to multiple criteria and uncertainty. This study hence emphasizes the selection of a suitable Multiple Criteria Decision-Making (MCDM) technique. The second part of the chapter then presents a literature review on the methods and decision-making approaches with special emphasis on the Analytic Hierarchy Process (AHP). The chapter ends with the discussion of the approach taken in the theoretical development of this research. This research concentrates on developing only one of the MCDM methods for the selection and evaluation of DSM options in buildings since it is a vast topic and the work done in this area is growing constantly. The literature review aims to identify the previous literature that has addressed issues related to energy management, DSM, criteria and DSM alternatives identifications, Delphi, decision making, MCDM, AHP and FAHP. Table 3.1 shows the keywords that were used in mining literature studies. At least one keyword from energy management should match one keyword from decision making.

Table1.3 Search Keywords

Energy Management Keywords	Decision making Keywords
Energy Management, Demand side Management (DSM), Integrated Resource Planning (IRP)	Multi Criteria Decision Making (MCDM), Analytic Hierarchy Process (AHP), Fuzzy Analytic Hierarchy Process (FAHP), Delphi method.

3.2 Demand Side Management (DSM)

3.2.1 Definition of DSM

The Electric Power Research Institute (EPRI) in the USA has defined Demand-Side Management as the following: "DSM is the planning, implementation and monitoring of utility activities designed to encourage consumers to modify their electricity consumption patterns, both with respect to the timing and level of electricity demand" (Gellings & Talukdar, 1985).

The broadest definition of DSM includes any utility activity designed to influence the pattern of customer electricity usage. DSM is becoming a universally accepted means for reducing utility-capacity needs and improving system operational performance (Rahman, 1996). Demand side management could be considered from two perspectives; the utility prospective and the consumer prospective. The utility prospective includes any activities from the utility side such as improving the efficiency of power plant, transformers, distribution lines, substations etc. The consumer prospective include any activities from the customer side, i.e. end uses appliances or measures.

From all the above definitions, it is clear that the concept of Demand Side Management contains the following:

- The concept of DSM usually refers to the electricity industry and is adopted by utilities
- DSM contains different activities from consumers in different sectors.
- DSM could be categorized into consumer side and utility side actions.

- The main objective of DSM is to modify and change the consumers load pattern to satisfy the utility's objectives.

3.2.2 Generic Load-Shape Changes

The broad definition of DSM includes all the activities, which involve actions on the consumer side of meter to change the utility's load shape. Figure 3.1 describes the generic load shape changes. The six methods shown in the figure are the principal means by which modern DSM programs can influence customers' demand for electricity. These methods are not mutually exclusive and may be employed in combinations. The six generic load shape changes, according to Gellings and Chamberlin (1993) include:

Peak clipping: Peak clipping means reducing consumption during peak time. This results in reducing mainly peak demand (kW) and sometimes energy consumption (kWh).

Valley filling: It includes building off-peak loads. This may be particularly desirable when the long-run incremental cost is less than the average price of electricity. This results in an increase in total energy consumption, without increase and often a reduction, in peak demand.

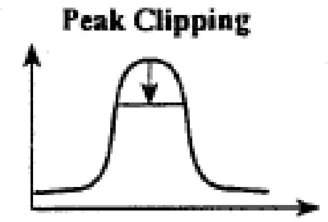
Load shifting: Load shifting involves shifting load from on-peak to off-peak periods. The net effect is a decrease in peak demand, but no change in total energy consumption.

Strategic conservation: Strategic conservation refers to reduction in end-use consumption. There are net reductions in both peak demand and total energy consumption.

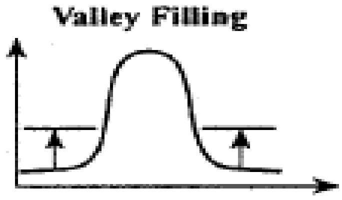
Strategic load growth: Strategic load growth consists of an increase in overall sales. The net effect is an increase in both peak demand and total energy consumption.

Flexible load shape: Flexible load shape refers to variations in reliability or quality of service. Instead of influencing load shape on a permanent basis, the utility has the option to interrupt loads when necessary. There may be a net reduction in peak demand and little if any change in total energy consumption.

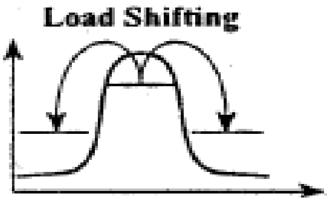
Load Shape Objectives and Effect on Load Shape — ***Means of Implementation***



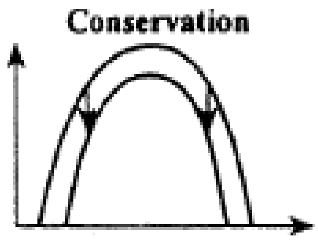
Utility control of consumer appliances



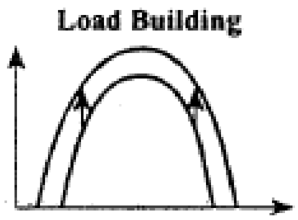
Thermal energy storage for A/C or water heating/space heating



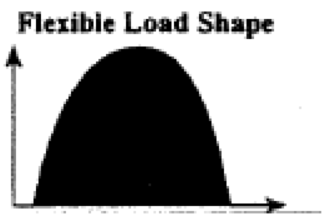
Time of use rates, storage devices instead of conventional appliances operation time



End-use efficiency



Addition of new end-users.



Interruptible and curtail able rates.

Figure 3.1 DSM load shape objectives (Gellings & Chamberlin, 1993).

3.3 Benefits of DSM

An inspection of DSM literature reveals that the benefits of DSM can be divided broadly into the following four categories.

- Strategic benefits
- Economic benefits
- Environmental benefits
- Social benefits

3.3.1 Strategic Benefits

The most important strategic benefits of DSM will be: (1) reducing the expenditure in power generating system, reducing the dependency on foreign fuel sources in case of fuel importing countries, and increasing the opportunity of fuel exports in the case of exporting countries. (2) Delaying the investment in new power plant projects. It is widely cited that DSM is a successful way of reducing the need for new generation capacity by improving efficiency in electricity end-use (Vine, 1996; Faruqui, 1989; Atikol et al., 1999).

The study of Winfield et al. (2004) and Lovins (1985) focused on DSM as a means to avoid the associated capital costs of new construction as well as any associated environmental impacts, financial or political risks. Their results support the argument that implementing DSM aspects is generally more reliable than the construction of new power generation.

3.3.2 Economic Benefits

In the case of DSM, from a national prospective the energy will be used in an efficient manner, thus enabling the utilities to deliver the same level of electrical service to customers with less generating capacity. This reduces the need of investment in the electricity system and the available budget will be shifted to other infrastructure projects. In addition, DSM increases the economic competitiveness since investment in demand side provides a better return than investment in supply side (Hajiah, 2006). From the consumer perspective implementation of DSM options not only reduces capacity and fuel consumption for the utility but the energy bills of the consumer (Reddy, 1996).

3.3.3 Environmental Benefits

The DSM programs can directly reduce the amount of energy consumption and thus will minimize the overall environmental impacts of generating plants and reduce the greenhouse gas (GHG) emissions, namely CO_2 (Reddy & Parikh, 1997). In addition, DSM decreases the other pollutants associated with the combustion of fuel in power plants; hence improves the overall health conditions.

3.3.4 Social Benefits

Demand Side Management activities can enhances the national energy security, reliability and availability of electricity system. DSM can create jobs through new markets in the energy market sector and increase the comfort and quality of work spaces, which in turn increases productivity (Hewett et al., 1995). A further benefit offered by Rowlands et al. (2001) is that "security of energy supply can also increase because fewer energy resources need to be imported for domestic resources will be able to meet demand for longer period".

3.4 Integrated Resource Planning

The traditional planning process is usually concentrated on supply-side options; in other words on building new power plants to meet the future load growth. However, in recent years the utilities have begun to consider demand-side options to meet projected load. Demand Side Management is feasible in situations where the cost of DSM is lower than the cost of supply.

The planning and energy policy context in which DSM and other innovative approaches to energy efficiency have been most effectively implemented is called Integrated Resource Planning (IRP). Beuer and Eto (1992) describe the IRO as such:

> "IRP is the process for integrating supply and demand-side resources to provide energy services at a cost that balances the interests of all stakeholders. The goals of IRP have evolved from least cost planning and encouragement of DSM to broader, more complex issues including core competitive business activity, risk management and sharing, accounting for externalities, and fuel switching between gas and electricity".

Hu et al. (2010) concludes in a study that if China follows the Integrated Resource Strategic planning approach, it may be able to avoid or postpone up to 69GW of power generation in the period 2009–2015 and also could help mitigate 201.8 million tons of carbon dioxide (CO_2), 0.816 million tons of sulphur dioxide (SO_2), and 0.946 million tons of nitrogen oxides (NOx).

3.5 DSM Applications in Developing Countries

Many developing countries are experiencing a rapid growth in power demand. Similar to the more developed countries, there is a need to minimize generation costs while meeting development and environmental objectives. Atikol and Guven (2003), for instance, has raised the question "Which DSM technologies are feasible to apply in developing countries?" Moreover, he conducted a study which attempted to develop a decision making model to answer the question.

On the other hand, high income people, even in the developing countries, may be reluctant for implementing some DSM measures, especially when the electricity tariff is low. This problem could be faced in Kuwait and it has to be considered in the design and implementation of any DSM programme.

Many developing countries have a good experience in applying DSM. Some of these countries have implemented successful DSM programmes resulting in significant energy and power savings. Examples of these countries are China, Thailand, and Brazil; their experience in DSM and lessons learned are discussed briefly below.

3.5.1 China

China has a long-term experience in implementing DSM. Recent DSM programmes, according to Nadel et al. (1995) have focused on four goals:

- Load Management – included considerable shift to the time-of-use (TOU) tariff; interruptible tariffs, and off-peak storage technologies like thermal energy storage air conditioners.
- Energy Efficiency – Economic and environmental benefits have been achieved with the adoption of a number of policies and actions that motivate the use of

efficient tools such as high efficiency lamps, adjustable speed drives, and high efficiency transformers.

- Energy Conservation – such as adjusting programmable thermostats and reducing the working hours operation strategies.
- Fuel Switching – formulation of incentive policies to substitute coal-burning plants with more efficient and environmental-friendly technologies.

There is a high potential of energy efficiency improvement in China while meeting its growing demand for energy services. Also China could eliminate the need for the construction of several new power plants by investing in demand side management (Hu et al., 2005). The estimated savings can reach almost 60 GW of power by 2020 which will be equivalent to operating 200 average power plants (300 MW each) (Hu, et al., 2005).

3.5.2 Thailand

In 1993, Thailand initiated a US $189 million DSM programme to reduce the electricity demand growth and promote energy-efficient equipment (Singh & Mulholland, 2000). From 1993 to 2000, the DSM programme succeeded in reducing peak load by an aggregate of 556 MW, or 4 percent of the Electricity Generating Authority of Thailand's (EGAT) total 1999 capacity. The cumulative annual energy savings were 3,140 GWh, representing more than double the original energy savings programme targets. The programme also reduced carbon dioxide emissions by 2.32 million tons per year (Singh & Mulholland, 2000).

One of the successful Thailand DSM project was the transformation to high efficient technologies, for example the fluorescent light market, increasing its market share from 40% to 100% , the market share of efficient refrigerators increased from 12% to 96%, also the share of efficient air conditioners increased from 19% to 38% (Birner & Martinot, 2002).

3.5.3 Brazil

Brazil has one of the largest electricity consumption in the world. The total annual energy consumption has grown from 70 to 300 TWh in the last two decades. (Hu et al, 2005).

3.6 DSM Technologies in Literature Review

This section reviews the literature in the field of DSM technologies in buildings. It starts with reviewing the literature highlighting the candidate DSM technologies suitable for buildings. Afterwards, it discusses the assessment methods for DSM technologies.

Table 3.2 lists several examples of DSM measures that were applied for commercial building sector for each of the six main load objectives (Bailly, 1995). As defined by Energy Information Association (EIA) of the US Department of Energy, the commercial sector is the group of non-residential customers who provide services, including retail, wholesale stores, hotels and motels, restaurants, and hospitals, as well as a wide range of facilities that would not be considered “commercial” in a traditional economic sense, such as public schools, governmental and insurance buildings, and organizations.

Table 3.2 Potential DSM Measures for Load Objectives Applied for Commercial Sector.

Potential DSM Measures	Peak Clipping	Valley Filling	Load Shifting	Strategic Conservation	Strategic Growth	Flexible Load Shape
Building Structure Fenestration	☼			☼		
Passive solar design	☼	☼		☼		
Ceiling and wall insulation				☼		
HVAC Heat recovery from exhaust air				☼		
Outside air economizer				☼		
Evaporative cooling	☼			☼		
Cool storage		☼	☼			
Heat recovery from chillers				☼		
High efficiency air conditioning	☼			☼		
Energy management systems	☼			☼		
Heat pumps	☼			☼		
Lighting Compact fluorescent lamps				☼		
LED lamps				☼		
High efficiency fluorescent lamps				☼		
Electronic ballasts				☼		
Light sensors				☼		
Light control (dimmers)				☼		
Day lighting controllers	☼			☼		
Electric Use Shifting & Control Demand controls	☼					
Power factor	☼					
Time of use rates	☼					
Motors						

High efficiency motors				☼		

Source: Bailly, H. "Demand Side Management" Manual, 1995, USA

Morsy and Al-Baharna (1995) have gathered detailed building characteristic data for about 500 buildings from the residential sector in Bahrain. These samples were selected from a total of 79,500 residences comprising flats, villas and traditional houses. The authors have carried out computer simulations to analyse electricity use in the Bahrain residential sector. They identified the following energy efficiency measures:

- Improving building insulation,
- Reducing infiltration rate,
- Energy efficient air conditioners,
- Increasing thermostat settings for space cooling,
- Efficient refrigerators and freezers,
- Compact fluorescent lamps, and
- Efficient water heaters

Sheen (2005) derived fuzzy profitability methods, which allowed the DSM to perform a financial evaluation between conventional air conditioning system and Cooling Energy Storage (CES) air conditioning system. The results demonstrate that the CES system is an effective tool for clipping peak demand and shifting electricity consumption to off-peak period.

Limmeechokchai, & Chungpaibulpatana (2001) proposed an assessment and comparison of different cool storage air-conditioning system in Thai commercial sector. Comparative economics of air-conditioning systems including the conventional one by Computer simulations were performed to evaluate investment and electricity costs with a number of tariff cases. Field evaluations were performed through interviews with decision makers, using AHP as a multi-criteria decision method.

Buildings were traditionally designed with equipment that operated independently such as air conditioning, lighting, computers, communications and security system and the like prior to the invention of Building Management System (BMS) or the implementation of intelligent building technologies (Loe, 1994; Robathan, 1994). There is a rapid development in building automation and control technologies which makes intelligent buildings with BMS more distinct than conventional buildings.

The DSM option screening process generally has three phases: (1) identification of potential DSM resources; (2) assessment of the various identified DSM options, and (3) selection of the most suitable DSM options for further consideration at later stages of the planning process (Schweitzer et al., 1991).

3.6.1 A Summary of DSM Technologies

Table 3.3 Summary list of DSM technologies from literatures

	DSM technologies
	Lighting system
1	High efficiency fluorescent lamps
2	Light emitting diode (LED) lamps
3	Electronic ballasts
4	Light sensors
5	Light control (dimmers)
6	Day lighting controllers
	Air conditioning
7	Ice storage air conditioners
8	High efficiency air conditioning
9	Cooling recovery system
10	Programmable thermostats
	Building envelop
11	Ceiling and wall insulation
12	Building management system
13	Reducing infiltration rate
	Automation and control systems
14	Building management system (BMS)

15	Demand controls
	Electrical system
16	Power factor
17	High efficiency motors

3.6.2 Assessment Methods for DSM Measures

As shown in Figure 3.2 (Gellings & Chamberlin, 1993), the DSM planning process has several discrete but interrelated steps, some of which are conduced iteratively; for instance, the results of the programme evaluation may guide the formulation of objectives of subsequent DSM programmes. The basic framework of DSM planning includes the following main steps:

1. Establish appropriate load shape objectives.
2. Conduct market research
3. Identify and screen the potential measures
4. End use analysis and evaluation of the program

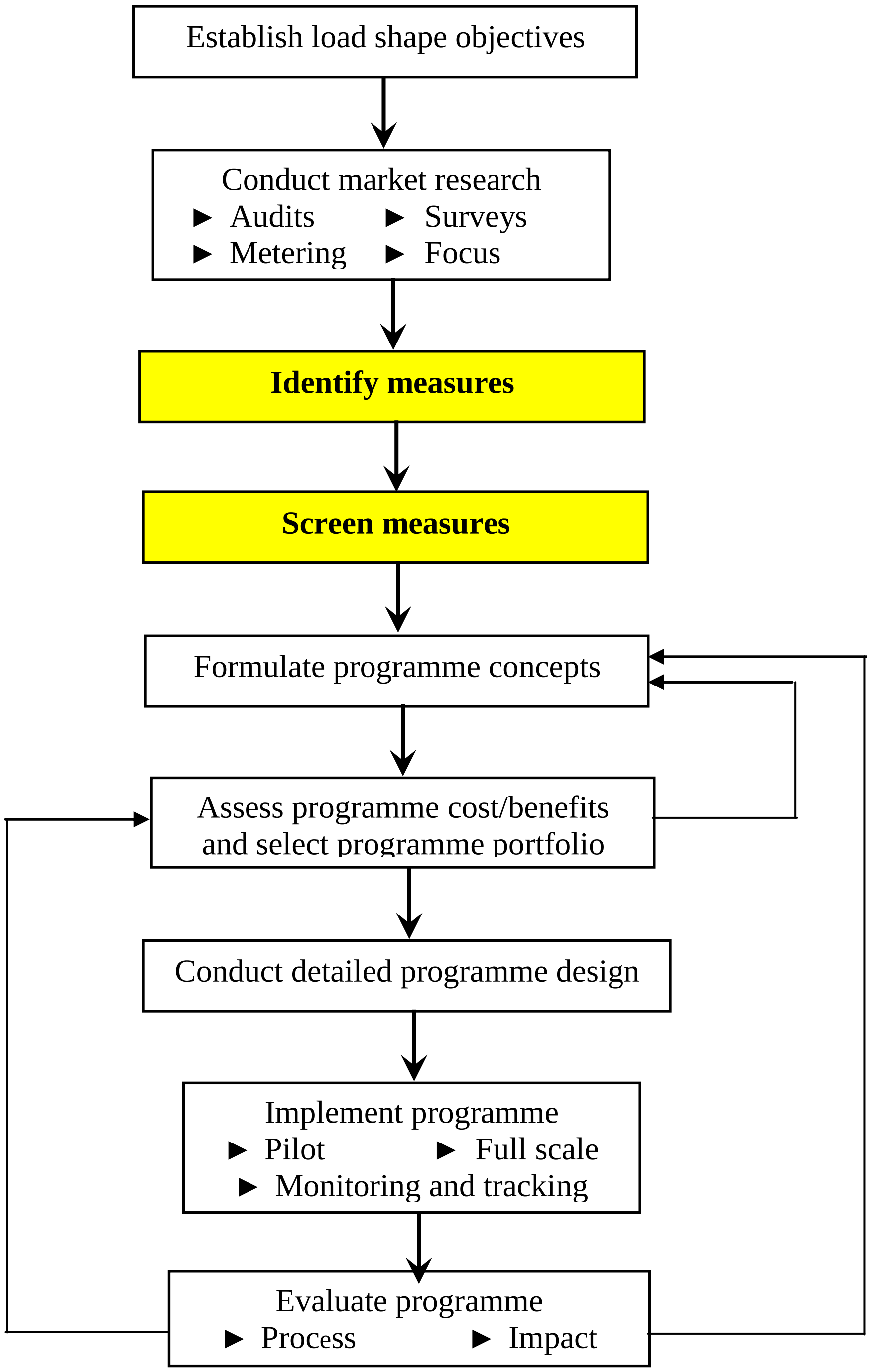


Figure 3.2 The DSM Planning Process (Gellings & Chamberlin, 1993).

3.6.2.1 Establish Appropriate Load Shape Objectives

The overall load shape objectives should be identified in order to select DSM alternatives. Based on the utility's requirements, load shape objectives are identified for the utility and for each consumer class. These objectives guide the DSM programme design and facilitate its implementation and evaluation.

3.6.2.2 Conduct Market Research

In the design of DSM programme the target population should be identified and take into account consumption patterns and opinion of that population. The required data can be obtained through customer surveys, billing analysis to establish a baseline for the programme impacts.

3.6.2.3 Identify and Screen Potential Measures

When the load shape objectives identified and the characteristics of the target market segment, several DSM alternatives can be used and evaluated against their technical and economic potential.

3.6.2.4 End Use Analysis

For the design of an efficient DSM programme that can achieve the action plan's load shape objectives, utilities must determine how customers make decisions about electricity consumption and how they use electricity. Market and load research is one of the effective methods used for data collection. Once the data is collected, they must be analysed to reach conclusions and results that would help utility planners with their decision-making processes and DSM designers to design efficient DSM programmes.

Information can be obtained by using one or more data collection instruments, which consist of detailed survey questionnaires, audit forms, and discussion and interview guides on the topics under consideration. Billing information and other customer-specific data available directly from a utility's databases can also be very useful, particularly for statistical approaches that do not require metering equipment. If computerized billing records are available, they can be a relatively inexpensive source of data for analysing customer's energy usage patterns. However, billing in many developing countries, including Kuwait, is subject to difficulty since it may be difficult to download to a statistical package. Moreover, there may be errors in the billing data, or large variations in the billing cycles for particular customer classes.

A different approach was proposed and adopted by Atikol (2004), who considered just the hotel sector. A survey was conducted to collect data about hotel buildings in northern Cyprus, where tourism energy demand is high between the commercial sectors. The survey was carried out and questionnaire sent to all hotels, to gather information about the installed capacities of water and space heating, cooling, lighting and refrigeration and their operation hours. The results of Atikol's study had shown the possibility of reducing peak load and energy consumption by adopting the following DSM options:

- Air-conditioning cycling control
- Slot-key switch
- Compact fluorescent lamps
- Gas-fired water heaters.

According to Rahman (1996), the engineering approach needs a prior knowledge of hourly DSM impacts. However, such impacts are hard to predict as DSM activities are diverse and inconsistent from one day to another.

3.6.3 Economic Assessments Methods:

Akbari et al. 1996 presents a cost/benefit investigation of energy efficient options for residential buildings in Bahrain. Based on the collected data and using DoE-2 computer program, nine prototypes were adopted for residential buildings and simulated their energy consumption. Technologies included: energy efficient air conditioners, insulating houses, reducing infiltration, increasing thermostat settings, efficient refrigerators and freezers, efficient water heaters, efficient clothes washers and compact fluorescent lights.

Reddy and Parikh (1997) identified 12 DSM options for the industrial sector in India. The analysis presented in this study presents modelling of technical options by using the COMPASS Model. The COMPASS (Comprehensive Market Planning and Analysis System) model was developed by the Synergic Resources Corporation. COMPASS can run benefit/cost analysis of various DSM options and strategies. It also provides system impacts and economic evaluations of complete DSM plans. The results of this study demonstrate that DSM programmers can reduce power demand and reduce pollution levels, particularly for CO_2 emission, through decreased energy consumption. They emphasized the fact that economic, political and physical criteria should be considered to achieving these targets.

Yang (2006) explored the best cost-effective DSM technologies in Nepal by investigation and interviews for power utilities and several electricity consumers in Nepal to collect data, as well as walk-through auditing at the consumers places. Financial and economic study methodologies were used to project cost-effectiveness evaluations. This paper concludes DSM technologies in Nepal include power factor correction; energy-efficient lighting in the residential and commercial sectors, and the installation of intelligent motor controllers for industrial induction motors are financially viable and most cost-effective technologies.

Lee and Yik (2002) presented a conceptual framework for formulating a performance based incentive-rebate scale within a DSM scheme. The proposed method leads to benefits, both for the commercial building owners and the utility companies; it also enhances the success of rebate-type demand side management (DSM) programs.

3.7 DSM Evaluation Criteria in Literature Review

This section of literature review aims to identify previous studies that focus on addressing the identification of the criteria for DSM selection in buildings or other related fields. The sources of criteria for the selection of DSM in buildings are limited and in many literatures not clearly defined. This contrasts with decision quality requirements where the criteria source should be identified; in other words, the rationale for the choice of criteria should be provided in order to produce a reliable outcome. Consequently, the decision makers' assessment of the suitable DSM in buildings consistently lack the identification of clear criteria.

As Greening and Bernow (2004) state, finding out or defining the most important factors or criteria of the DSM evaluation process is not an easy task. Performing an extensive review of the literature relevant to the field will give an opportunity to define the commonly used factors and criteria; this practice also applies for Demand Side Management technologies identification process.

In the following literature review the section will present the investigation process for a set of crucial criteria that were considered in selecting the optimal DSM technologies for buildings in previous research. For example De Wilde et al. (2002) developed a model of energy saving building selection based on six general criteria for building components evaluation. Figure 3.3 illustrates the model including criteria.

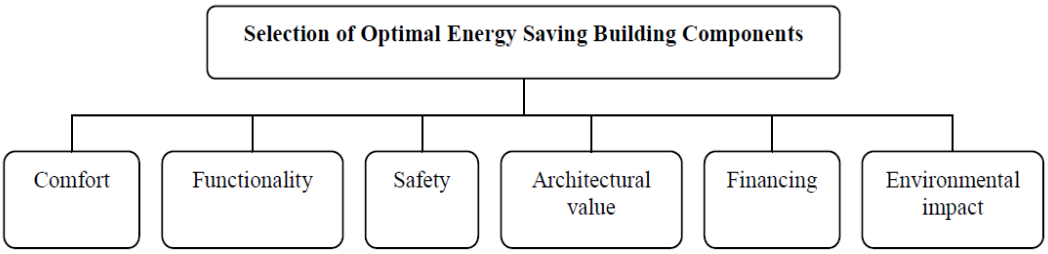


Figure 3.3 Model of the selection of the Energy Saving Building (De Wilde et al., 2002).

Hobbs and Horn (1997) presented a three-method Multi Criteria Decision Making approach to test the decisions of stakeholders by applying two or more methods and screen DSM programs. The results yielded by alternative MCDM methods confirm that can disagree and that a multi-method approach builds insight and confidence. The criteria in the study were defined by the stakeholder group during a series of meetings and were extracted from a multi-criteria exercise involving many of the same stakeholders conducted in previous years. To facilitate the assessments, the criteria were classified into two groups; an environmental/social group and an economic group. The identified criteria are listed below:

1. Environmental/Social criteria group:
    a. Environmental impact
        i. Minimize loss of environmental habitat
        ii. Minimize emissions of manmade greenhouse gases
        iii. Minimize emission of other air pollutants
    b. Social and economic impacts
        i. Promote job creation and retention
        ii. Conserve energy
2. Economic criteria group:

a. Quality energy service to customers at minimum cost
    i. Total resource benefits
    ii. Flexibility in resource selection
b. Minimize rates
    i. Ratepayer benefits
c. Provide utility shareholders value for their resource investment
    i. Shareholders risk

Schweitzer et al. (1991) conducted a descriptive data analysis on a national sample of US utilities to test selected utility characteristics and the mix of resources selected for the integrated plan including the use of DSM resources. He addressed the screening for the selection of DSM options of the energy planning process and the findings from the Survey of 24 Electric Utilities in the United States. Respondents rated the importance of seven criteria without mentioning the source. The survey asked utilities representatives to rate the importance of six different criteria in selecting options for their long-term resource plan. These criteria were: (1) cost, (2) environmental concerns, (3) flexibility, (4) reliability, (5) electric rates, and (6) capacity equivalence.

Malik presented a study for DSM energy saving and load management potential in commercial and government/institutional sectors in Oman. The study explored the DSM economic energy saving potential from utility and customer prospective. The estimation of DSM potential was based on a survey of six large shopping malls customers and six large government/institutional end users and the study evaluated impact of DSM on generation capacity and energy savings. Also an estimation of the energy savings in transmission and distribution (T&D) losses considered by applying the generation expansion planning method.

The study results show that it is beneficial to implement DSM in commercial and government sectors. The energy consumption can be reduced up to 21% and 38%, respectively in if applying DSM programs in the government and commercial sectors.

Mundaca and Neij (2009) developed a framework for the evaluation of Tradable White Certificate (TWC). The criteria used cover economic, social and environmental issues, which are listed below:

(i) Energy saving

(ii) Environmental effectiveness

(iii) Economic efficiency

(iv) Cost-effectiveness

(v) Transaction costs

(vi) Political feasibility

(vii) Administrative burden

(viii) Technical change

Lee et al. (2007) applied the Multi Criteria Decision Making (MCDM) for the evaluation of energy efficiency and greenhouse control plan as well as evaluating technology priorities. The main criteria used were UNFCCC, economic spin-off, technical spin-off, urgency of technology development, and quantity of energy use. While the sub-criteria cover the possibility of developing technologies, potential quantity of energy saving, market size, investment cost, and ease of energy use.

In his PhD thesis Catalina (2009) proposed a Multi-Criteria Decision Making aid for improving the development of renewable energy systems to facilitate the choice of technologies. The study also identified three criteria which were found best suited to express the advantages of the multi-source systems:

1- Energy Reduction MWh/year; this criterion was referred to as the *primary energy reduction* criteria.
2- Payback time on the investment year; this criterion was referred to as the *economic potential*.
3- CO2 reduction avoided tones of CO/year; this criterion was referred to as the *environmental criteria*.

Also the author recommend the application of a larger number of criteria (i.e. degree of implementation and mean life time) for further research.

In the past two decades, rapid development in building automation including microprocessor technologies strongly support the intelligent building; the technology life cycle is also considered as a critical factor (Wigginton & Harris, 2002).

Clements-Croome (1997) pointed out the relation between the well-being of humans comfort and the technologies and defined the following characteristics in determining the criteria for Intelligent Building in a study in 2004:

- High energy efficiency
- Environmentally-friendly
- Security and Substantial safety
- Well-being and convenience
- Lower life cycle cost
- Long term flexibility and marketability

The study of Rahman (1996) argues that there are many possible ways of evaluating DSM options; however Cost-benefit analysis, for example, is an efficient process for selecting cost-effective programs by screening a large number of scenarios. The screening process involves estimating DSM investments, operations and maintenance costs, as well as their energy and demand effects.

According to the above literature, it is clear that many studies concerned with the financial factors in DSM evaluation, have paid little attention to the non-financial factors. Yang and Peng (2001) argue that the reason behind focusing on the financial evaluation approach by decision makers goes back to the lack of information and support for decision making.

A review of DSM literature reveals that many DSM evaluation approaches are limited to the evaluation process with single criterion and this is what Hobbs and Horn (1997) argue in their study, that no single criterion can effectively address all the concerns embedded in complex decisions, a Multi-Criteria Decision Making deals as substantial advantages (Ding, 2008).

Traditional single criteria in energy planning solving problem aimed at exploring the relationship between energy and economy through the maximization of benefits or the minimization of costs as mentioned by Pohekar and Ramachandran (2004). The growing trend in global environmental awareness and the need for social considerations in the last two decades have played a significant role for the increasing use of Multi-Criteria approaches. Also, the previous handling of the decision problems into a single criterion was not well accepted.

Table4.3 Examples of DSM Evaluating Criteria and Identifying Sources

Category	DSM Evaluating Criteria	Literature Source	Year	Method
Technical	Reliability, voltage quality and environmental factors		2003	LIRP, on a distribution feeder of an investor-owned power distribution utility operating in Philippines
	Reliability, efficiency	Arif S. Malik	2007	The end-use (lighting and air-conditioning) energy consumption data have been collected through questionnaires
	Efficiency, maturity	Jiang-Jiang Wang et. Al	2009	Review methods in different stages of multi-criteria decision-making for sustainable energy, i.e., criteria selection, criteria weighting, evaluation.
Environ mental	Environmental GHG emission	K. Amirnekooei, et.al	2012	Long-term energy planning for Iran is simulated and analysed by applying several integrated resources strategies based on different forecasting methods Bottom-up analysis is performed using LEAP (long-range energy alternative planning).
Financial	Cost-effectiveness, utility cost, society cost	Joel Swisher	1996	The use of area-specific utility costs to target intensive DSM campaigns
	Cost-effectiveness, cost benefit analysis and sub-criteria (Unit cost / avoided peak cost)	Liu Deshun et al	1997	The cost-effectiveness of DSM application was assessed by using critical indicators, i.e. averaged unit cost of electricity saving and unit cost of peak avoided
	Cost	Alessandro Di Giorgio et al	2013	Event driven model predictive control approach for a local energy management system, enabling residential consumers to the automated participation in demand side management (DSM) programs
Social	human comfort	Qureshi et al	2011	Assessment of the impact of using phase change material in building material from an electricity demand side perspective, especially in the wholesale electricity market
Others	Quality, cost, environmental and social factors	Mills et al	1996	Developed a computer-based decision support system
	Readiness for improvements, characteristics of energy end user, impact on tariffs, emission reduction	Ilze Dzene et al	2011	Sophisticated screening method based on theoretical and practical basics of decision-making is proposed

Using multiple criteria to select optimal DSM technologies in buildings is not yet a common practice as seen in previous literature studies. The use of multiple criteria for the evaluation of DSM was investigated in literature related to DSM and energy management. Only in limited studies was there a recommendation to the use of multiple criteria to support the selection of DSM programs in buildings.

A review of the literature on DSM and energy management shows that the research area in the evaluation of DSM is segmented; on the other hand, previous research efforts lack general agreement on the selection criteria and there is a shortage of a developed model of general critical criteria for the evaluation. The relevant criteria for the selection of best DSM technologies in building, which have been widely discussed in the literature, are compiled and presented in Table 5.10. These criteria form the basis for the first research phase and development of decision making model.

3.8 Decision Making Process

Harris (1998) defines Decision Making (DM) as such:

> "Decision making (DM) is the study of identifying and choosing alternatives based on the values and preferences of the decision maker(s). Making a decision implies that there are alternative choices to be considered, and in such a case we want to identify as many of these alternatives as possible but the idea is to choose the one that best fit with our objectives and values".

According to Baker et al. (2002), decision making should establish with the identification of the following:

1) Decision maker(s) and stakeholder(s) in the decision
2) Minimizing the possible conflict about problem definition, goals and criteria

He also proposed a standard decision making process can be divided into 8 steps, illustrated in Figure 3.4. Brief description of each step is presented on the right side of the figure.

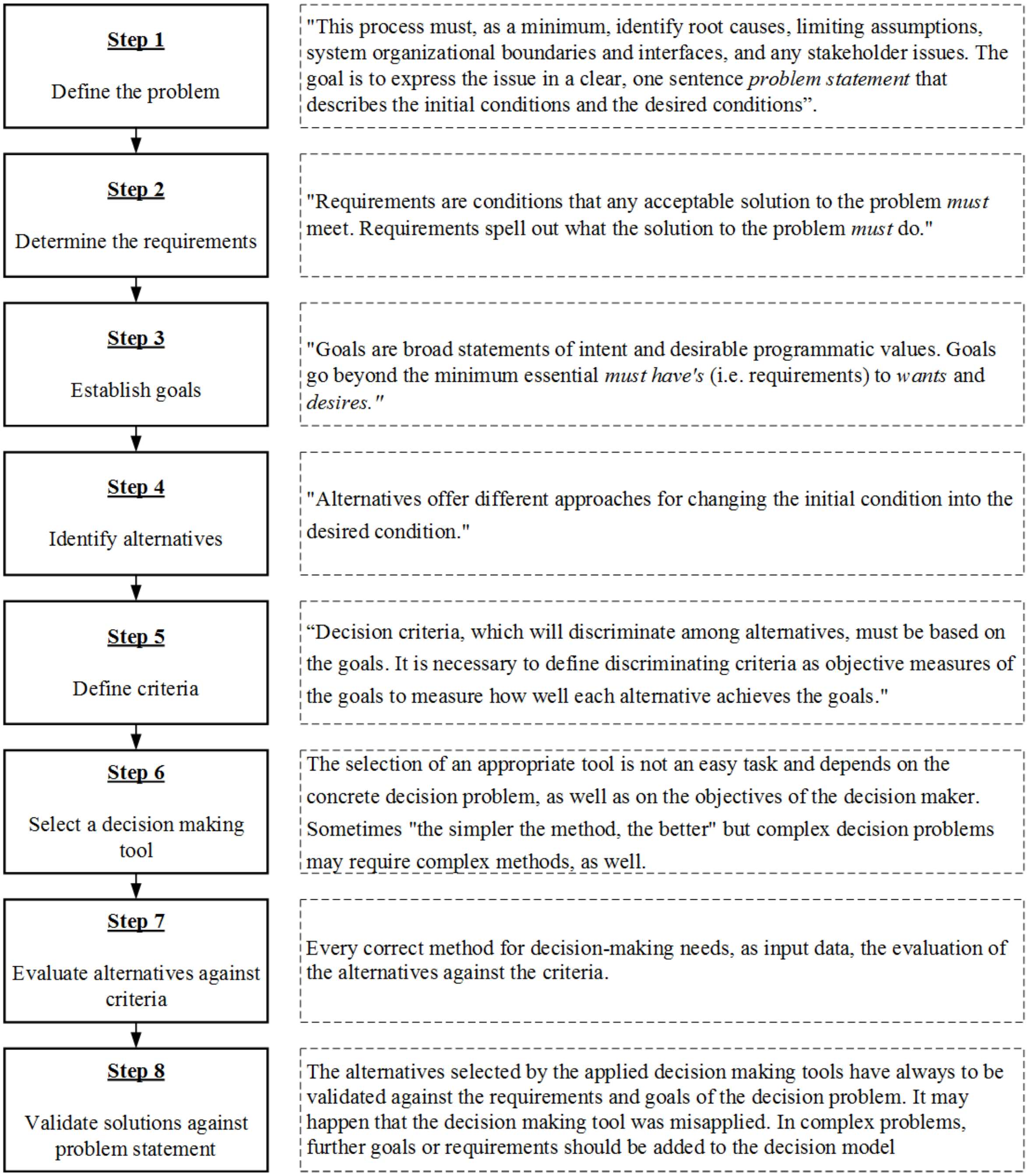


Figure 3.4 Steps of Decision Making Process.

Baker et al. (2002), emphasize that the decision criteria should be:

- Able to differentiate among the alternatives to help the comparison of the performance of the options.

- Comprehensive to include all goals
- practical and meaningful
- Non-redundant
- limited in numbers

DSM encompasses planning, evaluation, implementation and monitoring of activities selected from a variety of DSM alternatives (Gellings & Smith, 1989). The selection of the best strategy and/or technology applications may include conflicting quantitative and qualitative criteria and multiple decision makers. For example, the selection of appropriate DSM technology options may include: capital investment cost, amount of energy and demand savings, payback period, reliability, etc. Thus, the selection and evaluation of different DSM options (alternatives) could be classified as a Multi-Criteria Decision Making (MCDM) problem.

Classification of MCDM Different could be according to the type of data they use. Thus, there are deterministic, stochastic, or fuzzy MCDM methods (Triantaphyllou, 2000). Another classification of MCDM methods is according to the number of the decision makers who participated in the decision making process. For example, single decision maker MCDM techniques or group MCDM decision making. It is a common way to arrange the criteria into groups of one level of main criteria, second level of sub-criteria, and three level in sub-sub-criteria in a tree-structure arrangement (UK DTLR, 2001).

According to the techniques used, Goicoechea et al. (1982) divides MCDM into three groups:

1. Outranking techniques,
2. Multi attribute decision making techniques, and
3. Mathematical programming techniques

Ching-Lai and Yoon (1981) suggested that the MCDM problems could be classified into two main groups:

- Multi objective decision making (MODM), and

- Multi attribute decision-making (MADM)

The main difference between MODM and MADM methods is concentrated in the decision space. In the MODM method the decision space is continuous and decision options are not pre-identified, while in the MADM method, the decision space is discrete, where each candidate option can be assessed using a combination of analytical tools.

Zhou et al. (2006) classifies Decision Analysis (DA) methods into three main categories: Single objective decision-making methods, decision support systems, and MCDM. The study conclude that the Analytic Hierarch Process (AHP) (18%) is the most popular method, followed by Multi Attribute Utility Theory (MAUT) (17%), Multi Objective Decision Making (MODM) (14%) and Decision Tree (DT) (14%).

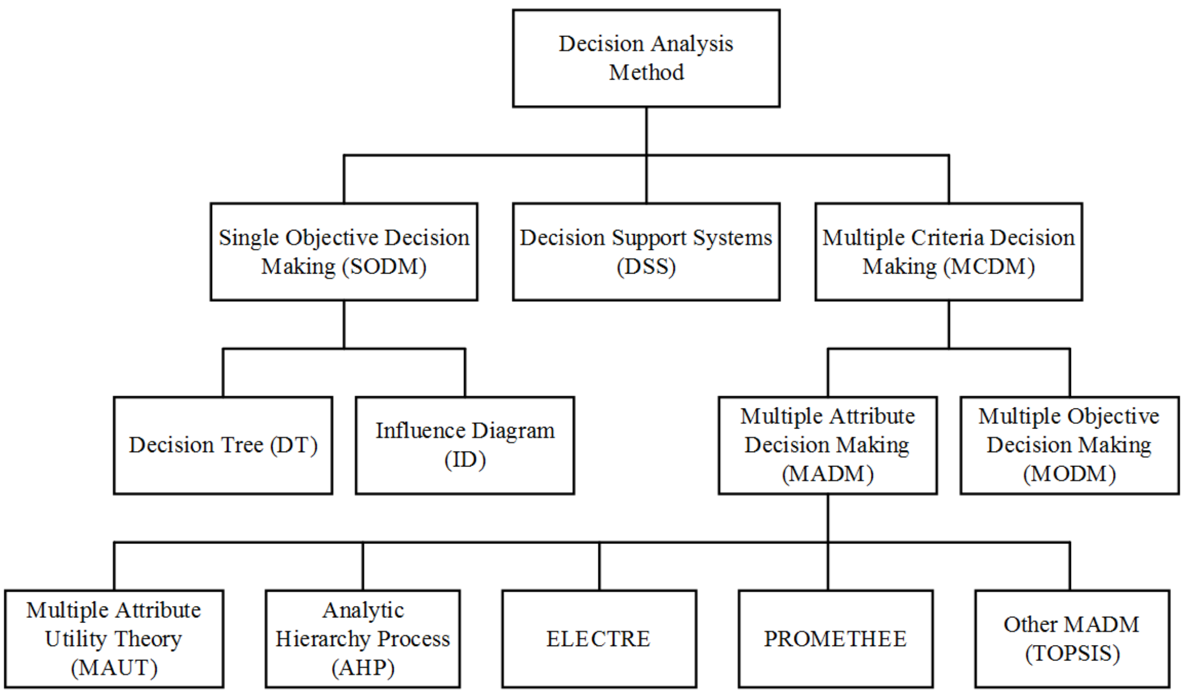


Figure 3.5 Classification of decision analysis methods (Zhou et al., 2006).

MCDM methods have shown to be prevalent and commonly used by researchers (Janic & Reggiani, 2002).

In this research, the selection and evaluation of the alternatives of the DSM technologies in buildings are considered as a problem of MCDM/MADM. The decision makers might encounter a number of alternatives in making their decision. A number of criteria might be considered by the decision makers, which might also conflict with each other. Consequently, the approach taken in the theoretical development of this research is to view the selection and evaluation of DSM technologies in making multi-criteria decisions.

3.9 Multi Criteria Decision Making

Multi-criteria decision-making (MCDM) techniques are often used in the field of energy and integrated resource planning (Hobbs & Meier, 1994; Hobbs & Horn, 1997; Huang et al., 1995).

According to Simonovic (2002), the MCDM problem is generally based on the following principles:

1. A set of candidates options (e.g. DSM options)
2. A set of criteria
3. A number of decision makers
4. A preference weights
5. A set of performance evaluation of options for each criterion

The first applications of MCDM evaluation to energy planning date back to the late 1970s and dedicated to power systems planning problems. The interest in multi-criteria evaluation has been gaining popularity since then, in particular due to the trend for market deregulation and the growing need for incorporating economic, environmental and social goals in energy planning (Diakoulaki, Antunes and Martins, 2005).

The following section introduces a literature review for two main decision making branches: MODM and MADM. Special emphasis will be given to MADM methods, where the number of criteria and alternatives is finite. Then the appropriate method for this study will be selected.

3.9.1 Multi Objective Decision Making

Multiple Objective Decision Making (MODM) is aimed at optimal design problems in which several (conflicting) objectives are desired to be achieved simultaneously. The purpose of MODM is to choose the ‘best’ alternatives among a potentially infinite set of alternatives.

The final optimal solution usually given through mathematical programming and multiple objectives have to transform into a weighted single objective. Therefore, a process of obtaining the trade-off information between the considered objectives should first be identified.

MODM problems are solved by several optimization models, such as goal programming, compromising programming, constraint method, and fuzzy multi-objective programming, which are elaborated in the following sections.

3.9.2 Goal Programming

Goal Programming (GP) was initially introduced by Charnes and Cooper (1961). Nowadays GP is acknowledged as one of the most effective strategies used in multi objective optimization problems. The method requests decision makers to determine goals for each objective that they want to achieve. A preferred solution is then defined as the one that minimizes the deviations from the goals (Lu et al., 2007). When one goal reaches the targeted value, another one may move away from its own target, therefore the objective’s function in GP modules is usually minimizing deficiencies from the aimed values.

Ignizio (1994) gives an algorithm that shows how a pre-emptive GP can be solved as a series of linear programs. Pre-emptive GP should be used when there is an existing clear priority order among the goals to be achieved. One of the advantages of GP method is that multiple criteria can be incorporated into a model that can be solved using single criterion optimization software. The disadvantage is that the decision maker's preferences information needed in advance in the form of priority levels, importance weights, and objective target values.

3.9.3 Compromise Programming

Compromise programming (CP) is a mathematical programming technique for use in continuous context (Zeleny, 1973). It is similar to goal programming in that it uses the concept of minimum distance. CP calculates the composite distance from an ideal point on the direction preferred by the Decision maker. The optimization problem exists while planning package for various combinations of weights or directions to create a set of efficient solutions. The best compromising solution can be found or a set of desired compromise solutions can be identified.

3.9.4 Constraint Programming

In the Constraint Programming method, the main performance index will be the most essential criteria or attribute while others are considered as constraints by given that a proper tolerance level to each of them. A set of efficient solutions can be identified by varying the tolerance levels as the compromising method. A feasible solution under the condition that all constraints on the criteria are binding at the optimal solution and consider as an efficient solution.

3.9.5 Fuzzy Multi Objective Programming

In this method the evaluation done through the shape of membership functions assigned to problem objectives and constraints. The application of fuzzy set theory could considerably reduce the decision making space as compared with multi objective programming models. The Fuzzy Multi Objective Programming method has been developed to solve multi-objective optimization problems with fuzzy objectives and constrains (Zhu & Chow, 1997).

3.9.6 Multiple Attribute Decision Making

Multiple Attribute Decision Making (MADM) include evaluating, and/or prioritizing a finite set of known alternatives and using both quantitative and qualitative decision constraints.

MADM techniques have been used in electric utilities strategic planning to help decision maker in selecting the best resource strategy or DSM options, with regard to the chosen attributes. Ching-Lai and Yoon (1981) published a comprehensive survey of MADM methods and applications.

3.9.7 Multi Attribute Utility Theory

The Multi Attribute Utility Theory (MAUT), developed by Keeney and Raiffa (1976) depend on aggregation of the different criteria into a function, which need to be maximized. Thereby the mathematical conditions of aggregations are examined. This theory allows complete compensation between criteria, i.e. the gain on one criterion can compensate the lost on another (Keeney & Raiffa, 1976).

The main advantage of MAUT is that the problem becomes a single objective problem once the utility function has been exactly assessed, and then ensuring achievement of the best-compromise solution (Keeny & Raiffa, 1976).

3.9.8 Outranking Methods

Outranking Method (OM) is one of the main families of MADM methods. It consists mainly of two classes: the Choice Translating Reality techniques including ELECTRE I, II, III, and IV techniques; and the Preference Ranking Organization techniques for Enrichment Evaluation (PROMETHEE).

Outranking methods assist as one alternative for dealing with complex choice problems with multiple criteria and group participants (Rogers & Bruen, 1998). .

Figueira et al. (2004) conducted state-of-art surveys for multiple criteria decision analysis including outranking methods. Below is a brief outline for the two most popular categories of the outranking techniques, the ELECTRE and the PROMETHEE.

3.9.8.1 The ELECTRE Methods

The Elimination and Choice Translating Reality (ELECTRE) methods were originally developed by Roy (1968). This technique is capable of dealing with discrete criteria of both quantitative and qualitative nature and provides complete ordering of the alternatives. The problem is that it should be formulated in such a way that it chooses alternatives that are preferred over most of the criteria and that do not cause an unacceptable level of discontent for any of the criteria. The ELECTRE method begins with pair-wise comparisons of alternatives under each of the criteria separately.

The ELECTRE method only produces a core of main alternatives. This method has a clearer view of decision making alternatives by eliminating less preferred ones, which is especially suitable when handling few criteria with a large number of alternatives (Pohekar & Ramachandran, 2004).

3.9.8.2 The PROMETHEE Method – (Brans et al. 1986)

Preference Ranking Method for Enrichment Evaluations (PROMETHEE) technique is one of the most introduced outranking methods and has been used more frequently recently. (Pomerol and Barba-Romero, 2000) The method introduces six preference function (generalized criteria) types to describe the decision making preferences. According to Brans et al. (1986), PROMETHEE has the advantage over ELECTRE of robust results able to survive threshold modifications.

3.10 The Analytical Hierarchy Process

Analytic Hierarchy Process (AHP) is a decision-making technique developed by Thomas L. Saaty (1980). This method introduce a systematic process for making optimal logical decisions in complex decision situations characterized by conflicting criteria and uncertainty (Saaty, 1990).

3.10.1 AHP Principles

The fundamental rule of the AHP is that the use of actual data and the knowledge and experience of experts are equally important in the decision making process (McIntyre et al., 1999). Decisions made using AHP occur in two sequential stages:

1- ***hierarchy design***, *hierarchy design* involves decomposing the decision problem into a hierarchy of decision elements (i.e., goal, evaluation criteria and solution alternatives)

2- ***hierarchy evaluation***; and *hierarchy evaluation* involves eliciting weights of the criteria and alternatives preferences to determine stakeholder alternative priorities.

Figure 3.6 illustrates a three AHP level hierarchy for selecting an appropriate option. At the top of the hierarchy is the goal or the overall objective. In the second level the criteria which affect the choice of the best alternative. The lower level include of the alternatives under consideration for satisfying the overall decision goal. Arranging the goal, criteria and alternatives in hierarchy support the decision maker to understand the relationships between decisions elements and assess the importance of each issue at each level and minimize the decision problem complexity.

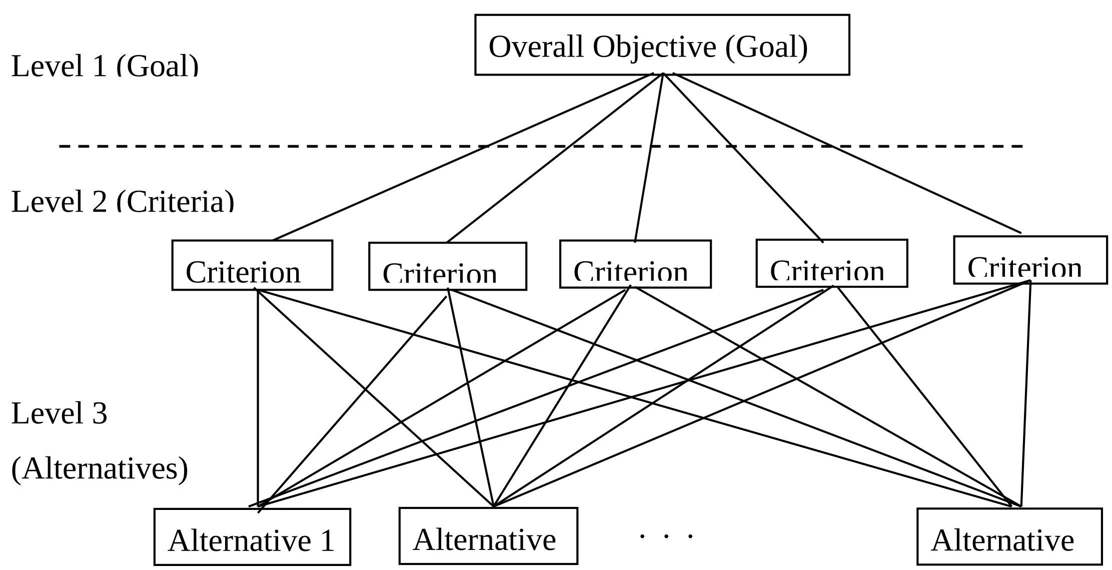


Figure 3.6 Graphical representation of the hierarchy structure of the AHP method

Thomas Saaty (2005) emphasis that decision processes include intangible criteria that can be hard to capture by human understanding and highlights the importance of deriving relative priorities in decision process. Figure 3.7 shows the detailed logic flow diagram for AHP methodology.

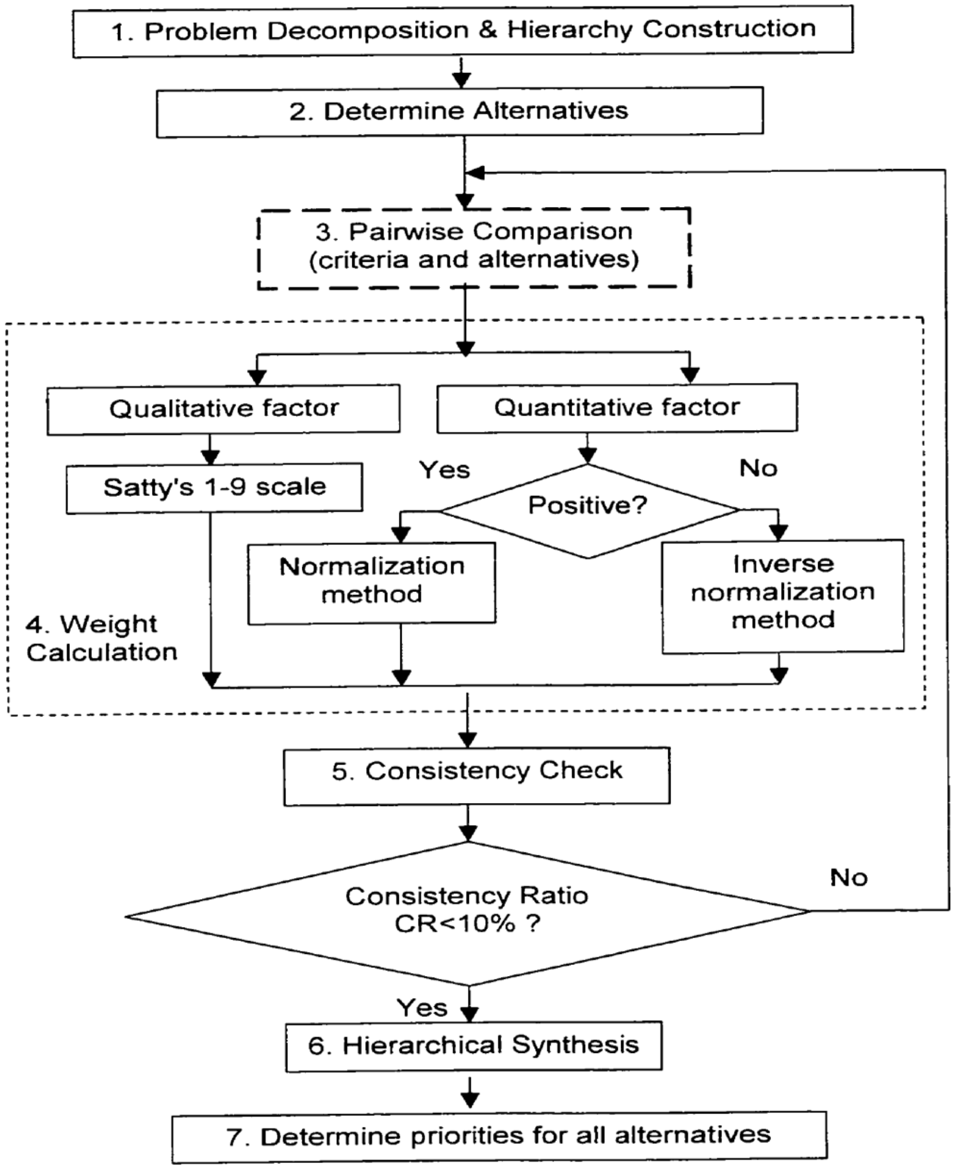


Figure 3.7 Detailed logic flow diagram for AHP methodology (Saaty, 1990)

AHP depends on an Eigen value method for the pairwise comparisons. It also provides a technique to calibrate the numeric scale for the measurement of quantitative and qualitative performances.

3.10.2 AHP applications

As noted in (Saaty and Vargas, 1991) at least twelve types of problems may be addressed by the AHP, which include:

1. Setting priorities
2. Generating a set of alternatives
3. Choosing a best policy alternative
4. Determining requirements
5. Allocating resources
6. Predicting outcomes/Risk Assessment
7. Measure performance
8. Designing a system
9. Ensuring system stability
10. Optimizing
11. Planning
12. Conflict Resolution

Vaidya and Kumar (2006) emphasis that the developing countries need to use tools like AHP for the evaluation and selection of the complex economic and other systems. Based on an extensive review of a total of 150 AHP application papers, the following observations highlight the course of future AHP applications:

1. AHP is going to be used widely for decision making.
2. The use of AHP is growing in the developing countries, which is predictable due to the rapid economic development in countries.
3. The advantage of AHP flexibility can assist in focus of Combining with other various methods.

4. Use of software applications will be support to handle the issue of complexities associated of AHP when combined with other techniques.

Subramanian and Ramanathan (2012) provide an extensive review of applications of Analytic Hierarchy Process method in operations management. The authors point out the extremely high number of existing papers on problems and applications in different fields; they systematically categorised the published literature from 1990 to 2009 in 291 peer reviewed journals articles and then analysed them methodologically. The analysis revealed that a significant number of AHP applications are found when the problem required both quantitative and qualitative consideration (e.g. socio-economic decisions).

This trend in publication history mentioned in previous two papers indicates a significant preference towards AHP over other decision-making models.

3.10.3 AHP in Energy Management

AHP is one of the more widely applied MCDM methods. It has been applied to a wide variety of utility decision-making problems. Vashishtha and Ramachandran (2006) presented an AHP evaluation model for DSM implementation in India. Ramanthan and Ganish (1995) used an AHP model for the evaluation of energy efficiency alternatives in the residential sector. Nagesha and Balachandra (2006) used AHP to identify relevant barriers to energy efficiency in small-scale industry in India. Malik and Sumaoy (2003) used AHP approach to evaluate the impact of DSM resources to planning criteria. Ramanathan (1999) used AHP for the selection of appropriate greenhouse gas (GHG) mitigation options.

Table5.3 The Analytic Hierarchy Process (AHP) in DSM and other related fields.

Author	Year	Field of Study	Aim of using AHP
Ramanathan and Ganesh	1995	Evaluation of energy sources for lighting	Used an integrated goal programming-AHP model to evaluate seven energy sources usable for lighting in households
Ramanathan	1999	Greenhouse mitigation (GHG) selection	A multi-criteria methodology - Analytic Hierarchy Process, has been suggested for making the appropriate selection.
Vashishtha and Ramachandran	2006	Evaluation of DSM strategies	Used AHP as multi criteria evaluation tool for demand side management (DSM) implementation strategies in the Indian power sector
Nagesha and Balachandra	2006	Energy efficiency barriers	Used AHP as multi criteria based for prioritization of Barriers to energy efficiency in small industry
Lee et al.	2007	Assessment of DSM investment programs	Develop a scientific and rational assessment model based on AHP for demand-side management investment programs (DSMIPs) in the areas of natural gas and district heating
Lee et al.	2007	Energy resource planning	A scientific procedure to determine the priorities in energy resource technology development to make a strategic long-term national energy and resource technology by using AHP.
Wang et al.	2010	Energy resource selection	Evaluates coal, petroleum, natural gas, nuclear energy and renewable energy resources as energy alternatives for China through use of a hierarchical decision mode based on AHP method.
Selvakkumaran	2012	Assessment framework of energy security	Used assessment framework, (named Holistic Energy Security Index) to evaluate and prioritized six dimensions of energy security by using AHP
Tanoto et. Al	2013	Assessment framework for demand side management planning.	Proposed multi-dimensional assessment framework of Residential Lighting Demand Side Management (RLDSM) including AHP as MCDM tool

3.10.4 Why AHP? A Justification of the Application of AHP

Many literature reviews reveal the reasons for choosing AHP as a tool to assess the preferences of stakeholders for specific research problem; brief accounts of reasons are highlighted below:

1. The AHP model decomposes the problem into a hierarchical structure which enables the decision makers/stakeholders to visualise the problem systematically in term of relevant criteria, sub criteria and alternatives (Darvish et al., 2009).
2. AHP is a quantitative procedure applied to multi criteria decision problems and has capabilities to enable a medium for quantifying the qualitative features to reduce subjectivity in decision making (Partovi, 2001; Scott, 2002; Mishra et al., 2007).
3. By using pairwise comparison features, the AHP allows for many objectives to be simplified to individual choices. Pairwise comparison will make assigning weights much easier for participants because only two objectives are being compared at any one time.
4. The AHP pairwise comparison scale makes it easy to create a pairwise comparison matrix for each relevant element of a problem.
5. AHP provides an inconsistency check test that enables the elimination of illogic or rush answers (Coyle, 2004).
6. AHP method represents a consensus of experts. Lee et al. (2007)
7. Availability of support commercial AHP software makes the calculation easy and provides many show tools for quick viewing of the results.
8. AHP method has been accepted as a leading multi-attribute decision model both by practitioners and academics (Gass & Rapcsák, 2004). Also, several researchers recommend AHP as a better decision-making method than most of other decision making methods. AHP method in the rank-order weighting method is more and more prevalent because of its understandability in theory and the simplicity in application (Pohekar & Ramachandran 2004).

The AHP method seems attractive because the pairwise comparison form of data input is straightforward and adequate. However, the rank reversal problems have caused some limitation, where rank reversal refers to the fact that when new additional alternative added to the candidates alternatives which does not change the range of outcomes of any criteria may lead to a change in the ranking of the other alternatives (Belton and Stewart, 2002).

Peniwati (1996) investigates the comparison and contrast between AHP and other approaches such as the Delphi Method, Matrix Evaluation, Goal Programming and Outranking Method to problem structuring, ordering and ranking. The conclusion considers AHP as the most comprehensive method compared in being mathematical valid and in producing accurate results. Other decision-making techniques are not necessarily in competition with each other, and the integration of methods could be complementary as it would remove any limitation associated with each one.

AHP is considered among a wide range of application areas in being an excellent research method tool, but compared to other multi-criteria evaluation methods reviewed, the combination of Delphi method with AHP and Fuzzy AHP application to DSM evaluation and assessment for buildings is still a novelty.

The AHP offers a rational way to evaluate qualitative design issues. The hierarchical structure of criteria helps organize the problem. It also has the advantage of being relatively simple to use, although it may be time consuming if there are many criteria and alternatives to evaluate. A number of specialists highlight a number of concerns about the AHP, including the potential internal inconsistency and questionable theoretical foundation of the rigid 1-9 scale, as well as the phenomenon of rank reversal possibly arising when a new alternative is introduced, which was addressed by Belton and Stewart (2002) previously. At the same time, several modifications have been made to the original methodology proposed in order to retain the strength of AHP (Saaty, 1980). Some of the modifications have resulted in the development of the Fuzzy AHP, which is further investigated below.

3.11 Fuzzy AHP Concept

The AHP method as explained in previous section has been widely used to solve multiple-criteria decision-making problems. The crisp pairwise comparison with a conventional AHP may be unable to precisely capture the decision maker judgment due to the vagueness and uncertainty of the decision maker judgment, (Ayag, 2005).

Fuzzy AHP is a synthetic extension of classical AHP method when the fuzziness of the decision maker is considered. Fuzzy is introduced into the pair-wise comparison to deal with the shortage in the classical AHP and to deal with the vagueness of human thought, Zadeh (1965) first introduced the fuzzy set theory, which was oriented to the rationality of uncertainty. A major contribution of the fuzzy set theory is its capability to represent vague data. The earliest work in fuzzy AHP was introduced by Van Laarhoven and Pedrycz (1983), which compared fuzzy ratios described by triangular membership functions. Essentially, the uncertainty in the preference judgment gives rise to uncertainty in the ranking of the alternatives as well as difficulty in determining consistency of preferences (Leung & Cao, 2000).

3.11.1 Applications of Fuzzy AHP Methodology in Literature

The Fuzzy AHP has been used to solve various multi criteria decision problems. Yu (2002) explore the advantage of goal programming to solve group decision making fuzzy AHP problem. Weck et al., (1997) assessed the alternative production cycles using fuzzy AHP. Sheu (2004) utilized the fuzzy approach to identify global logistics strategies. Kulak and Kahraman (2005) used fuzzy AHP for multi-criteria selection among transportation companies. Ozdagoglu (2007) conducted a comparative study between classical AHP and fuzzy AHP.

Examples for the application of the fuzzy AHP, the assessment of water management plans (Sredjvic & Medeiros, 2008), critical decisions in new product development (Buyukozkam & Feyzioglu, 2004), safety management in production (Dagdeviren & Yuksel, 2008), and the selection of enterprise resource planning systems (Cebeci, 2009).

Shahin and Poormostafa (2011) propose an integrated approach of simulation, fuzzy AHP and Quality Function Deployment for facility layout design improvement and optimization where the results reveal an indication that the proposed integrated approach enhances problem solving in facility layout.

Yang et al. (2003) indicated that one basic application of fuzzy set theory is fuzzy synthetic evaluation, which is a decision-making approach within a fuzzy environment. Also AHP can provide a comprehensive and consistent analysis on the weights of all problem constraints and both methods can provide the same benefit.

Based on the covered literature review on MCDM, AHP and FAHP, and the progress developed for its improvement as well as the brief fuzzy explanation of the previous paragraphs, it was decided that to support AHP method Fuzzy-AHP (FAHP) is the best approach for this research study. This selection is based on the following main reasons:

- Since fuzziness and vagueness are common characteristics in many decision-making problems, a fuzzy AHP method should be able to tolerate vagueness (Mikhailov & Tsvetinov, 2004).
- Fuzzy AHP may solve any hierarchical fuzzy problems associated with AHP, such as uncertainty associated with the mapping (Zhu et al., 1999).
- The addition of a fuzzy approach to the conventional AHP model can support a clearer decision framework while greatly enhancing the efficiency of the screening process (Smimou et al., 2001).

3.11.2 Fuzzy AHP in Energy Management

There are numerous cases of employing fuzzy AHP in other fields; however few researches have been done with FAHP in building energy management area. According to Zheng et al. (2010), FAHP proposed a method to assess building energy performance where seven factors include (building structure, wall, roof, door and window, heating and air conditioning, equipment, and energy) and 22 sub-factors were defined and incorporate in the assessment model. The research findings indicated that (air conditioning and heating), wall, equipment, and energy are the four most important factors in the assessment model. Also the conclusion emphasized that the FAHP method is convenient and objective for the assessment of building energy conservationn performance.

Shen et al. (2010) used Fuzzy AHP to resolve the multi-goal problem to reveal the suitable renewable energy sources for the purposes of meeting energy policy goals. Zeng et al. (2013) proposed a new management of the whole process evaluation of DSM projects based on Fuzzy AHP approach which combines Analytic Hierarchy Process and fuzzy comprehensive evaluation method to evaluate DSM projects management considering the whole process. This study analyzes key factors of every stage of DSM projects combining with the whole process theory and proposes a new evaluation indicator system in order to promote the development of DSM projects management. Li (2012) adopted FAHP method to evaluate the Energy Performance Contracting (EPC) financing bottleneck in China.

Table6.3 Examples of (FAHP) in DSM and other related fields.

Author	Year	Field of Study	Aim of using FAHP
Zheng	2010	Building Energy Management	Proposed a method to assess building energy performance
Shen et al.	2010	Renewable Energy	To resolve the multi-goal problem to reveal the suitable renewable energy sources
Zeng et al.	2013	DSM Project	Proposed new management whole process evaluation of DSM projects based on Fuzzy AHP approach

3.12 Techniques of Data Collection

Data collection techniques include screening literatures, observation of behaviour, face-to-face interviews, telephone interviews, and mail questionnaires. These techniques are often not inadequate to achieve the quality or quantity of the information required. Accordingly, survey instruments may be necessary to gather primary data from which judgments about programmes or technology assessment can be made (Summerhill and Taylor, 1992).

3.13 Face-to-Face Interviews

Face-to-face interviews have a distinct advantage in enabling the researcher to establish personal communication and make it possible to gather more information for the research study. These interviews are usually more accurate than other data collection methods, yield highest response rates and allow the researcher to clarify when appropriate.

Three types of face-to-face interviews are commonly used in practice: semi-structured, in-depth and structured. Semi-structured interviews are very loosely structured, consist of open-ended questions that define the chosen topic, and are usually supported with a semi-structured questionnaire. The in-depth interviews often cover one or two issues in detail and questions are based on what the interviewee says; also, the questions are the least structured of the three mentioned types. The structured interviews consist of administrating structured questionnaires; trained interviewers ask fixed choice questions in a consistent format. In the structured research face-to-face interviews, the questionnaire design plays an important role, where specific and closed questions are usually used.

The key points that need to be considered while conducting an interview are the need for consistency between the research question and objectives, the strategy to be employed and the methods of data collection to be used. The structured face-to-face interviews with structured questionnaires are used in this research study, due to the consistency between research questions and objectives and the reliability of data collection.

3.14 Delphi Method

Strategic studies can be considered as an activity that aims to support strategic policy making in the areas of technology and science where expert opinion is often taken into consideration to give new value added knowledge on complex problems. Formerly, it was common to gather expert opinions in meetings or long discussion interviews. Nowadays, technology assisted tools such as e-mail and websites to solicit and exchange information are more often used and facilitate the expert's opinion in easier ways for many reasons like saving time, making proper decisions without direct external individual's influences, and recorded feedback. The Delphi method is an example of this kind of technique.

3.14.1 Background on Delphi

The Delphi method is the most common qualitative method and is recommended as a long-range forecasting technique to elicit future trends or to provide probabilities for different scenarios in becoming a reality by refining the collective opinions of experts (Schmidgall, 1997). It is also applied widely to a variety of problems in different fields. A panel of experts in the field answers questions or provide opinion through well-organized questionnaires or meeting agenda.

Initially, the Delphi technique was developed by the RAND cooperation to predict military issues, ranging from long-term threat assessment of technological and social development

(Dalkey, 1969). Since then, this qualitative approach has attracted much attention in a variety of other industries (e.g. education, business, and IT) including power and energy resources because policy development requires long term predictions (Moutinho et al., 1995).

Delphi has considered as a supportive analytical techniques to gather a valuable vision on issues involving a high level of uncertainty in several research area. Significant studies have been carried out using Delphi technique to assess the social impacts of developments, (Menard et al., 1999; Cuhls et al., 1998; Loveridge et al., 1995; Loveless et al., 1996; Benari, 1988). Delphi is widely used as a good technique also for dealing with complex problems (Fitzpatrick et al., 1991; Pinyerd et al., 1993).

3.14.2 Characteristics of Delphi

Four key features to Delphi method procedure are: iteration, anonymity, controlled feedback and a group statistical response (Landeta, 2006; Rowe & Wright, 1999; Schwarz, 2008). The main function of the method was to obtain the most reliable consensus of judgment from a panel of experts by conducting single or many rounds of questionnaires with controlled opinion feedback.

The main advantages of the Delphi process is subject anonymity, which can reduce the effect of dominant individuals, and often is a concern when used to gather information under group based approach (Dalkey, 1969).

The traditional Delphi method consists of participant's evaluations about the issues through the successive rounds of iterations to show consensus of opinions. This interaction process among the experts over several rounds gives them feedback from the previous rounds, and experts make arguments and evaluations of some issues to delineate futures scenarios (Tapio, 2003; Ronde, 2003).

3.14.3 Advantages of Employing Delphi Technique

Typically, Delphi is implied for one of the following reasons as recorded by Linstone and Turoff (1975):

- The team of individuals required to contribute to solving the particular problem have diverse backgrounds or a history of communication problems.
- The number of individuals required is very large and thus, face-to-face interaction would be ineffectual.
- Group meeting are not feasible due to time and cost constraints.
- Current face-to-face meetings are inefficient and need to be streamlined.
- Current communications between individuals are disruptive or politically biased.
- Certain individuals have dominating personalities and preserving heterogeneity requires anonymity.

Shneiderman (1988) has highlighted two main advantages of Delphi method:

(1) All decision-makers (experts) are deeply involved in the evaluation process because the Delphi method allows them to suggest what criteria or objectives should be considered in the analysis; this will lead to reaching more agreement on criteria or objectives selected.

(2) Because of its anonymity, the Delphi method allows the experts to express their opinions freely and to assign numerical values to what is essentially an opinion, even though an educated one. The experts are given the opportunity to express their subjective value judgments for each criterion or objective and can be assured that their judgments will be taken into account.

The Delphi method, an expert-based tool, has been widely used as an application to solve complex problems involving economic or social phenomena (Landeta, 2006; Ronde, 2003). Delphi is used as the primary or secondary research method to study construction related topics (Arditi & Gunaydin, 1999; Gunhan & Arditi, 2005). The application of the Delphi method in the DSM, however, is very limited.

3.14.4 Disadvantages of Delphi Technique

Limitations of Delphi method have also been identified and raised by many researchers. Sackman (1975), for example, pointed out that because responses may not be traced back to the individual, anonymity may lead to a lack of accountability. It could be argued that all similar approaches to gaining consensus run this risk. Others have argued that this approach is time consuming, labor intensive and, therefore, expensive (Fitzsimmons and Fitzsimmons, 2006), although there is no unanimity on this (Powell, 2003).

A number of methodological issues arising in respect to Delphi method have the capacity to threaten the credibility of the study and these include issues around:

- Number of rounds for consensus
- Panel expertise selection
- Questionnaire development
- Achievement of consensus
- Analysis of results

The main limitations in above points are the consensus, the number of rounds and the analysis of results, which are addressed in section 3.14.5. However, in relation to the panel selection point, one can argue that the degree of expertise of the panel members may be uneven and difficult to assess. Clear conditions and criteria could be identified for the experts and stakeholders as conditions for Delphi participants. Many Delphi applications discard these limitations and consider that the technique has been, and will continue to be, an important data collection methodology gather information.

3.14.5 Consensus in Delphi Technique

The Delphi process can be continuously iterated until consensus is determined to have been achieved. However, Cyphert and Gant (1971), Brooks (1979), Ludwig (1994, 1997), and Custer et al. (1999) point out that three iterations are sufficient to collect the needed information and to reach a consensus.

The major statistics in Delphi studies are measures of central tendency (means, median, and mode) and level of dispersion (standard deviation and inter-quartile range) in order to present information concerning the collective judgments of respondents (Hasson et al., 2000). Also, the uses of median and mode are favoured. However, in some cases, as manifested by Murray and Jarman (1987), the mean is also workable. In the literature, the use of median score, based on Likert-type scale, is strongly favoured (Hill & Fowles, 1975; Eckman, 1983; Jacobs, 1996).

3.14.6 Delphi in Energy Management

Delphi technique has been used in various studies related to the energy sector. For example, California Energy Commission used the Delphi method to forecast the crude oil price and its impacts in future (Nelson et al., 1996). Also the Delphi method is used to explore the technological developments in electricity industry (Lefebvre et al., 1996; Iniyan et al., 1998).

Makkonen et al. (2012) have explored the future obstacles that could affect the competition in the European electricity markets. Sharma et al (2003) conducted a Delphi study to consolidate expert opinion on various critical issues to the power sector of Kerala in India.

Yang et al. (2010) identified the indicators of energy efficiency assessment in residential building in China through a wide literature review, specifically:

- The existing building assessment methods
- The existing Chinese standards and codes in building energy efficiency
- Academia research

After extensive comparison between AHP and Delphi, the author used AHP method for weighting the indicators in building energy efficiency assessment instead of Delphi. The main reason was because AHP needs only one round communication with experts' as a result, the AHP method takes lesser time and cost than the Delphi method, hence is more advantageous.

Hsueh and Yan (2011) developed an evaluation model and implied Delphi method, Analytic Hierarchy Process (AHP), and fuzzy logic for sustainable community construction low-carbon development effectiveness, in order to compare community low-carbon and energy saving development levels. The Delphi method was used to work out evaluation factors with expert knowledge contents as the benchmarks for evaluation; the generated criteria to evaluate the performance of low-carbon community construction projects can be used by government as a reference.

Daim et al. (2012) proposed approach to evaluate energy storage technologies for investor-owned or public utilities. The study employed a technology evaluation process integrating fuzzy Delphi method, Analytic Hierarchy Process and fuzzy consistent matrix. The evaluation criteria structure in AHP was constructed on the basis of results from a literature review and an assessment of expert opinions. The identified criteria fell into technical, economic, environmental and social perspectives. The result showed that compressed air storage is the most promising technology for sustainable growth of renewable energy in the region.

Social aspect and Delphi method considered in many studies related to energy; for example, Ferreira et al. (2010) used the combination of Delphi and AHP methodologies to illustrate a possible process of social evaluation of the future electricity plans assigning a numerical scale to each individual option. Table 3.7 lists examples of Delphi method in DSM and other related fields.

Table7.3 Examples of Delphi method in DSM and other related fields' research.

Author	Year	Research topic	Aim of using Delphi	Panel size	No. of rounds
Sharma et. al	2003	Prospects of power sector	To provide valid consensus among experts on various critical issues that affect Kerala power sector	107	2
Hsueh and Yan	2011	Sustainable development and energy conservation	To provide sustainable community construction integrated evaluation model for project selection	12	2
Daim et. al	2012	Energy storage technologies	proposed model to evaluate energy storage technologies	12	-
Ferreira	2012	Integrated electricity planning	AHP/Delphi model used for the prioritization of electricity generation options.	12	2

.In order to investigate the potential application of DSM measures in the governmental buildings, and to select the most promising DSM technologies, Delphi method will be used as explained in Chapter 4 .

3.15 Conclusions

DSM is the planning and implementation of those utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape (the timing and level of electricity demand). Utility programmes falling under the umbrella of DSM include load management, new uses, strategic conservation, electrification, customer generation, and adjustments in market share (Gellings & Chamberlin, 1993).

DSM has a substantial potential for electricity (energy and power) savings but, due to a wide range of barriers, this potential has not been fully exploited. This chapter reviewed the literature that covers two main issues related to this research; the first issue was related to DSM, including its concept, load shape strategies, benefits, assessment, and potential applications in developing countries. The second issue dealt with the methods used for Multi Criteria Decision Making (MCDM) problem and the methodology to select the best tool for solving it and the way to assess reliable information for decision-making.

DSM implementation involves different actors with conflicting objectives and different alternatives with varying implications in effectiveness, feasibility, efficiency, reliability and stakeholder acceptance. This necessitates a critical analysis of the range of DSM alternative measures to determine the preferred DSM programme or strategy, which can achieve maximum outcome.

The selection, evaluation and ranking of DSM alternatives is a complex Multi Criteria Decision Making (MCDM) problem. Literature review shows that many MCDM techniques are used in practice. These techniques are usually broadly classified into two main branches: Multi Objective Decision Making (MODM) methods and Multi Attribute Decision Making (MADM) methods. MODM problems can be defined and solved by several alternative optimization models such as compromising programming, constraint method, goal programming and fuzzy multiple-objective programming. In contrast, MADM methods are comprised of a variety of effective techniques, capable of handling complex problems such as selection, evaluation and ranking multiple alternatives (e.g. DM options).

Existing research lacks a thorough investigation into the DSM technologies selection in buildings. The review of DSM literature in this chapter indicated that a fundamental body of research has been conducted without considering multiple criteria or factors considered during the evaluation process of DSM in buildings. Fewer studies have been conducted to determine the attributes or criteria for DSM technologies assessment. These knowledge gaps have prevented decision makers from selecting the appropriate DSM technologies in buildings. There is no comprehensive list of criteria to asses and select DSM technologies, and also lack of a systematic approach to facilitate the selection of appropriate DSM technologies could lead to irrational selection.

The review of literature in the areas of DSM and Energy Management indicates that it is a flake one which lacks a general agreement on a set of crucial criteria for selecting the DSM technologies in buildings. After reviewing the literature related to the subject, the variables that might influence the selection of DSM technology in buildings could be generally classified into four criteria groups including, technical, financial, environmental and social aspects, each categorized as such:

1) Technical
   1-1 Flexibility for operation and maintenance
   1-2 Durability and reliability
   1-3 Reduction in consumption
2) Financial
   2-1 Capital cost
3) Social
   3-1 Comfort to users.
4) Environmental
   4-1 Impact on environment (CO_2, SOx, NOx)

AHP is one of the most widely methods used in decision analysis. It was selected as the method for use in this research study, due to its simplicity and transparency. AHP can also be combined with other methods, and it is easy to add alternatives (existing or dummy ones), to experiment with the sensitivity of parameters, or to estimate the outcome of an action (element sensitivity).

Most of the MCDM problems in the real world are associated with uncertainty and fuzzy environment and, thus, should be regarded as fuzzy MCDM problems, which consist of goals, aspects (or dimensions), attributes (or criteria), and possible alternatives (or strategies). In the traditional AHP, uncertainty and vagueness are disregarded; for this reason, it was decided to use the Fuzzy AHP (i.e. FAHP) for this research. This method can tolerate vagueness and uncertainty of human judgment, and helps decision makers to deal with imprecision and vagueness in pair wise comparison. The weighting values of decision makers could be, in this case, integrated with the general framework of fuzzy Hierarchical Multi-Criteria Decision-Making process.

Chapter 4. *RESEARCH METHODOLOGY*

4.1 Introduction

In Kuwait, Demand Side Management has a substantial potential for electrical energy and demand savings (MEW/R6, 1983). The potential of energy savings has not been fully exploited due to a wide range of barriers such as high subsidy electricity tariff, improper electricity billing systems, improper implementation of code enforcement and no continuous improvement for code of practice (MEW/R6). The main objective of this research study is to identify the feasible and robust DSM technology measures through a systematic approach for decision making, which could achieve a substantial reductions in electricity demand of the governmental sector. DSM Technologies alternatives considered are explicitly due to energy efficiency and conservation measures that could be realized independently of any additional policy measures. Although DSM policy measures, such as tariff restructuring and the application of power factor penalty, are very important for the promotion of DSM; these measures are not included in our study.

This chapter explains the overall methodology used for data collection in order to address research issues. The methodology utilized in this research is based on the experience-based approach, which means experts' opinion and decisions are consulted in order to find answers to the research questions. This approach takes into consideration the climatic condition of Kuwait and the extremely high demand for cooling air conditioning in summer.

This chapter is divided into three main sections, and explains methods and instruments used for data collection, providing a description of the techniques that are used in the research methodology. The first section presents the problem identification and study approach. The second section presents the screening process of DSM alternatives and criteria measures using Delphi process. The third section presents the selection of Multi Criteria Decision Making (MCDM) model and a description of analytic hierarchy process and the fuzzy approach in this process.

4.2 Problem Identification and Study Approach

As explained in literature review, there is a considerable gap in current studies with regards to overdependence on single-criterion decision making when evaluating the DSM technology selection in buildings. Single criterion can be a problem because other attributes, such as environmental, societal and technical concerns, may play an integral part in the acceptance of DSM technologies and lead to insufficient selection. That is why it is necessary to develop a model to facilitate multiple criteria to support energy decision making. The present work aims at helping to eliminate these limitations in the DSM decision making process and thus ensures the selection of the optimal DSM technologies in specific buildings through a systematic identification of criteria and DSM technologies.

The methodology utilized in this research is based on information assessment and the experience-based approach, taking into consideration the long experience of experts and local conditions.

4.3 Reasons for Selecting Governmental Buildings

In Kuwait, electricity consumption is divided into residential sector, taking the largest share (64%), followed by industrial (18%), governmental (10%), and commercial (8%) sectors (Hajiah, 2003). The choice of governmental buildings (schools, offices and religious buildings) as a case study was made for the following reasons:

1- Within each type of building, there are a lot of similarities in terms of design, operation and technologies. There are more than 1000 schools and 1100 religious buildings, and many governmental offices. (The Public Authority of Housing, authorised by the Government of Kuwait, is responsible for the design and construction of all Schools, religious places and many office buildings.) (http://www.housing.gov.kw/Attachments/Monthly_Report_nov_en.pdf)

2- Intermittent occupancy for the majority of governmental buildings offers a good opportunity for reducing peak demand by implementing demand management during non-occupancy periods. Schools and office buildings are typically occupied from 7am–2pm. Less than an hour is also taken for performing the five daily prayers in religious places (Kararti and Hajia, 2011; Al-ajmi, 2010; Budaiwi and Abdou, 2013).

3- Governmental buildings, owned and controlled by the Government, fit as a case study since facility managers and engineers have shown a willingness for more flexibility in implementing DSM policies and program in the future and consider this case study as sample (Al-Mulla et al., 2013).

4- According to MEW records, the three types of buildings considered as the highest consumers among other governmental buildings are school buildings, classified in the first rank, followed by religious places and office buildings. Maheshwari et al. (2001b) in an experimental study for programmable thermostat show that energy savings of 46%, 37% and 25% were achieved for schools, religious places, and clinics, respectively.

5- Energy management experience in Kuwait has a good experience with energy audits and pilot projects in governmental buildings compared to industrial or residential sectors (Al-Mulla et al., 2013; Alotaibi, 2013; Sabzali et al., 2012; Maheshwari et al., 2001b; Hamadah and Hamouda, 1997; Assem and Al-Mumin, 2010).

4.4 Research Approach

This research consists of three phases and evolves three major instruments; each instrument is used to solve a specific task, as follows:

Phase 1: involves an in-depth data collection through literature review and face-to-face interviews by local experts in energy management. The main objective of this phase is to prepare a pre-screening list of DSM alternatives and criteria.

Phase 2: uses a *Delphi procedure*, using a group of experts for screening and narrowing of data collected in phase 1, including the identification of potential DSM alternatives and criteria for further analysis.

Phase 3: uses the Analytic Hierarchy Process (AHP) to rank the identified DSM alternatives and criteria outcome of phase 2 through the selected decision making model; i.e. the AHP with fuzzy approach. The three phases of the study are deemed equally important in addressing the research objectives. Each phase of the study extracts essential data to assist and contribute to the development of the research instrument of the subsequent phase. Figure 4.1 shows the basic steps of the research methodology.

Figure 4.1 shows the basic steps of the research methodology.

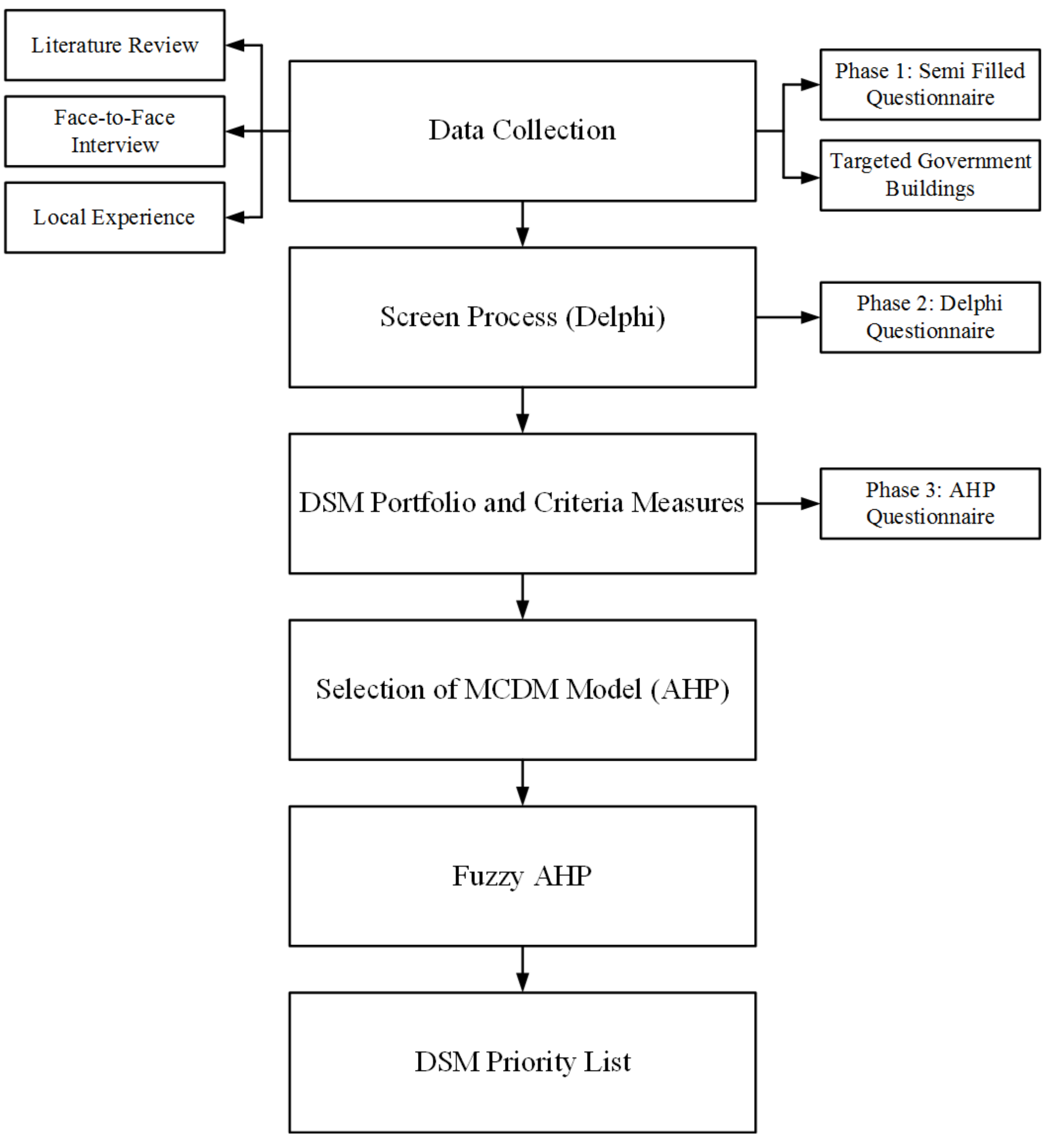


Figure 4.1 Steps of Research Methodology

Since the present research focuses on the selection and evaluation of appropriate DSM technologies and criteria of judgment, the panel of experts chosen are professionals in the fields of energy management. In choosing panellists for this study, the following criteria were used: experience in the field of energy management; extensive theoretical knowledge, a minimum of a bachelor's degree in engineering or a closely related research field with a minimum of ten years' experience (details are provided below).

Also to identify potential participants, support was sought from the local supervisor Associate Professor Dr. Mohammad Al-Hajri. Also assistance was provided by Dr. Ali Al-Ajmi from the College of Technological Studies (CTS) at Public Authority for Applied Education and Training (PAAET), Dr. Yahia Al-Habdan from Kuwait Institute for Scientific Research (KISR), and fellow colleagues, researchers, and business relations from the Ministry of Electricity and Water in Kuwait, where the author worked for nine years before being transferred to the Oil and Gas Industry.

Potential participants for this research were identified through their expertise in the area of energy management in the State of Kuwait. They included four groups: academics, consultants, owners, and contractors. The nomination of people, who were deemed appropriate as "energy experts" in this research, was based on the following general criteria:

Academics:

1- Must have a minimum of ten years working/teaching experience in energy management at a university or research institute.

2- Minimum M.Sc. and research interest in the areas of energy management.

3- Recommended fairly extensive publication in energy management.

Consultants:

1- Must have a minimum of ten years working experience in energy management.

2- Currently working as a consultant and providing energy management consultancy services in design and implementation of energy management projects.

3- Extensive theoretical knowledge in energy management.

4- Recommended MSc /PhD degree.

Contractors:

1- Must have a minimum of ten years working experience in energy management.

2- Currently working as an engineer and dealing with energy management.

Owners:

1- Must have a minimum of ten years working experience in energy management.

2- Currently working as an engineer and implementing energy management equipment for governmental buildings and representing the building owner.

3- Responsible for supervising the construction, operation and maintenance of buildings.

Only those experts who satisfied the above criteria were invited to participate by providing their opinions in subsequent questionnaires in each research phase. To ensure a holistic point of view, the questions were targeted at energy experts, including academics, consultants, contractors and government representatives or owners. The energy experts were selected from the initial selected nominations; forty two (42) respondents were invited to participate in this research; twenty eight (28) agreed to participate in the required research phases. Details of results from each research phase will be discussed in chapter 5 and chapter 6.

A list of the experts with their designation in the corresponding organization is summarized in Table 4.1. The names of experts who involved in research phases are kept anonymous in order to respect their anonymity as per research requirements.

Table 4.1 List of experts from the academic group who participated in research phases. KISR: Kuwait Institute for Scientific Research, PAAET: Public Authority for Applied Education and Training, CTS: College of Technological Studies.

Group	No of Experts	Designation	Years of Experience
Academics	3	Professor at Kuwait University, Mechanical Engineering Department	30
		Assistant Professor at Kuwait University, Mechanical Engineering Department	14
		Assistant Professor at Kuwait University, Mechanical Engineering Department	11
Academics	4	Associate Research Scientist at KISR, Energy & Building Technologies Department	15
		Assistant Research Scientist at KISR, Energy & Building Technologies Department	14
		Assistant Research Scientist at KISR, Energy & Building Technologies Department	12
		Senior Research Specialist at KISR, Energy & Building Technologies Department	25
Academics	6	Professor at PAAET, Mechanical Power and Refrigeration Technology Department	25
		Associate Professor at PAAET, (CTS) Mechanical Power and Refrigeration Technology Department	20
		Assistant Professor at PAAET, (CTS) Mechanical Power and Refrigeration Technology Department	15
		Assistant Professor at PAAET, (CTS) Mechanical Power and Refrigeration Technology Department	15
		Assistant Professor at PAAET, (CTS) Mechanical Power and Refrigeration Technology Department	14
		Assistant Professor at PAAET, (CTS) Mechanical Power and Refrigeration Technology Department	12

Table 4.2 List of experts from the owner group who participated in research phases. PAHW: Public Authority for Housing and Welfare, MAIA: Ministry of Awqaf and Islamic Affairs

Group	No of Experts	Designation	Years of Experience
Owners	3	Director Engineering Design Department at PAHW	25
		Supervisor Engineering Design at PAHW	20
		Senior Project Engineer at PAHW	20
Owners	4	Director Maintenance Department at MAIA	22
		Supervisor Engineering Section at MAIA	18
		Supervisor Energy Conservation Section at MAIA	16
		Senior Maintenance Engineer at MAIA	15

Table 4.3 List of experts from the consultant group who participated in research phases

Group	No of Experts	Designation	Years of Experience
Consultants	3	Consultant Engineer at Engineering System Groups	25
		Consultant Engineer at Engineering System Groups	24
		Consultant Engineer at Engineering System Groups	20
Consultants	3	Consultant Engineer at PACE Consulting Engineers	26
		Consultant Engineer at PACE Consulting Engineers	25
		Consultant Engineer at PACE Consulting Engineers	24

Table 4.4 List of experts from the contractor group who participated in research phases

Group	No of Experts	Designation	Years of Experience
Contractors	2	System Engineer at Kazema Global Holding	15
		Mechanical Engineer at Kazema Global Holding	12

The consultant companies (PACE and Engineering System Groups) are selected from the government's qualified list. They provide design consultation services for governmental building projects in Kuwait and represent the consultants group.

The selected contractor companies are also selected from the government's qualified list. They provide construction and installation works for governmental building projects in Kuwait and represent the contractor group. The contractor group was limited to 2 specialists due to a lack of availability of the specialists who can meet the minimum requirements for selection.

Energy experts play an essential role in the research phases. In particular, their participation is of great contribution in the following phases: phase one, the generation of criteria and DSM portfolio; phase two, screening of Criteria and DSM alternatives through Delphi questionnaire rounds; and phase three, the generation of alternatives to be analysed under AHP and FAHP.

The choice of energy experts was due to their important role in energy management communities as well as due to the provision of technical expertise.

4.5 Procedure of Data Collection

Data collection is conducted for the preliminary setting of the potential DSM alternatives in governmental buildings through literature studies, and also in identifying criteria measures for its evaluation. Three methods are used for data collection: literature review, face-to-face interviews and local experience in energy management. We focus on data collection in the assessment of DSM technology measures; policy measures are excluded from research investigation to narrow the research area and focus on the assessment of DSM options field.

4.5.1 Literature review

This section focuses on the summary of the potential DSM technologies addressed in Section 3.6.1. These technologies could be applied, in the global sense, in commercial/governmental sector. A special emphasis is given to the well-proven technologies and successful case studies suitable for the developing countries, particularly for the hot climates similar to that of Kuwait.

Primary criteria for evaluating DSM alternatives are also obtained from a study of the previous literature, and then modified and/or adjusted through face-to-face interviews and Delphi process. Examples of the criteria from literature review addressed in table 3.4. Criteria can be classified to four main categories: technical, financial, environmental and social. Example include: capital cost, payback period, ease of implementation, environmental impact, reliability and flexibility of operation and maintenance.

4.5.2 Kuwait Local Experience

No DSM programmes have been activated in Kuwait yet, however some energy efficiency efforts have been done during the last two decades. Several studies and energy audits, as well as several computer simulations have been conducted mainly by Kuwait Institute of Scientific Research (KISR). These efforts have been focusing mainly on office buildings, with special emphasis on air conditioning cooling loads, to reduce power demand in summer months. The energy efficiency of governmental and commercial buildings is still in need of improvements and there are many opportunities for potential energy saving (Alotaibi, 2011).

Due to the hot arid weather in Kuwait and extensive use of air conditioning systems, most of the KISR research work, energy audits and computer simulations are focusing on the reduction of peak load and performance optimization of A/C systems. Unfortunately, many governmental and institutional buildings allow the A/C systems to run on continuous basis, although these buildings are occupied only part of the day. Some studies conducted by a group of researchers from KISR (Maheshwari, et al. 2001) recommended the use of time-of-day control of indoor temperature through a programmable thermostat. The experimental data of using temperature offset control shows that energy savings of 46, 37 and 25% were achieved for a kindergarten, a religious building and a polyclinic, respectively. The optimization of operation and maintenance strategies in A/C and lighting systems for two office buildings were also audited by a group of KISR staff (Maheshwari, et al. 2004).

Assessment of the potential use of cool thermal storage was also investigated by KISR staff and other experts. The results of these studies demonstrate that cool thermal storage systems are well-proven technologies that can be implemented in Kuwait and can be very helpful in reducing the peak power demand growth.

Lighting systems are generally the second major contributor to the peak demand and energy consumption after A/C systems. For this reason, the second priority in energy audits and studies performed KISR is allocated to lighting systems. Roughly, lighting accounts for 15% of peak load and 20% of annual energy consumption (Al-Nakib, 1997). In most of the KISR audits in governmental buildings, it is recommended to replace conventional incandescent lamps to CFL or LED lamps and to use electronic ballasts instead of magnetic ones (Al-Nakib and Maheshwan, 1997; Al-Nakib and Al-Ragom, 2001).

In a recent study conducted by KISR in cooperation with MEW, the smart operation strategies for A/C and lighting systems were tested in eight governmental and institutional buildings. The total connected A/C and lighting loads of these buildings were 34.5 MW. Central A/C systems were used in all buildings, six of them used water-cooled chillers, and the other two had air-cooled chillers. The total cooling capacity of the eight buildings was 18817 RT. In all buildings, lighting systems shared about 15% of the power demand and 20% of the energy consumption. The type of lighting in all offices was linear fluorescent tubes (LFT), T12, equipped in most locations with magnetic ballasts. All buildings, except one (Justice Place Complex) had Building Management System (BMS) with different features. KISR’s project team developed, in consultation with facility managers, a baseline performance of each building before implementing smart operation strategies. Pre-Closing Treatment (PCT) was the first option to be implemented between 13:00h and 14:00h, when the buildings were still occupied. Full, or partial closure of fresh air, reduction in cooling production and distribution were the most common PCT measures. Time-of-day control (TDC) for air distribution, cooling production and distribution systems and lighting systems was the second option applied at 14:00h, at the end of the official working time in these buildings. Comfort levels monitored during the PCT and TDC implementation were reviewed and adjustments were made in the smart operation strategies to ensure that the temperature built up was within the acceptable levels. Also adequate pre-cooling strategy was implemented prior the start of work in the building.

This project has been one of the most successful approaches to reduce A/C and lighting peak loads in governmental buildings. Peak power reductions achieved in the project exceeded their target values. For example, PCT implementation between 13:00h to 14:00h achieved a reduction in power demand of 11.7% (3.43 MW) against a targeted value of 5%, while the TDC implementation after 14:00h achieved a reduction ranging from 34% to 45% (8.9 to 10.7 MW) against a targeted value of 20%. These savings are thus associated with considerable energy savings.

Additionally, this project identified and validated several shortcomings in current design and operational practices related to the A/C and lighting systems in the governmental and institutional buildings.

Table 4.5 List of potential DSM technologies in Kuwait governmental buildings

	DSM technologies	Method	Building type	Sources
1	High efficient Lighting systems	Experimental	Office	Al-Nakib, & Maheshwan (1997)
2	Programmable thermostat	Experimental	Kindergarten, religious building, clinic	Maheshwari et al. (2001)
3	Energy efficient glazing , lighting, cooling recovery unit	Simulation computer program (DOE-2)	Clinic	Al-Murad & Maheshwari (2001)
4	Cool thermal storage	Carrier chiller selection software, ECAT2 Version 4.12	Clinic	Sebzali & Rubini (2006)
5	Cool thermal storage	Economic assessment, simulation program (ESP-r), Life Cycle Cost (LCC)	Clinic	Sebzali & Hussain (2012)
6	Building glazing type	EnergyPlus building simulation program	Office	Assem & Al-Mumin (2010)
7	Shading A/C condensers	The comparison is based on a theoretical model and data from equipment catalogues	A/C in general	ElSherbini & Maheshwari (2010)
8	Power Factor Correction	Experimental	Office	Al-Mulla & Al-Otaibi (2011)

9	BMS	Detailed surveys and assessment of air-conditioning, lighting / BAS	Office	Al-Mulla et al., (2013)

The results of KISR studies mentioned above, specifically the DSM technologies identified in governmental buildings are considered in the discussion during face-to-face interviews and semi-filled questionnaires as described below.

4.5.3 The criteria and DSM technologies development

The research methodology started interviews with energy experts in order to answer the research objectives, to identify the potentially viable DSM alternatives, and to explore the criteria which influence the selection of DSM alternatives. Also the interviews were conducted to determine the key barriers for DSM implementation in in Kuwait and explore the need for decision making model to support the selection of DSM technologies in Kuwait governmental buildings.

Research Phase one: face to face interview

The methodology consisted face to face interview as a research instrument in phase one (the interview record sample is attached in appendix A). Concerning the interview content, the questions were designed to gather efficient information on the demand management field and DSM technologies in Kuwait. The purposes of face to face interview were to meet directly the energy experts and discuss the items related to research objectives and the identification of DSM and criteria which are listed below:

1. Current decision-making process dealing with selecting Demand Side Management technologies in mosques/schools/offices.
2. Barriers for implementing Demand Side Management technologies and energy management in Kuwait.
3. Demand Side Management technologies suitable for existing buildings (mosques/schools/offices).
4. Criteria to be considered when selecting Demand Side Management technologies for existing buildings (religion places/schools/offices).

5. Demand Side Management technologies suitable for new buildings (religion places/schools/offices) including emerging technologies.
6. Criteria to be considered when selecting Demand Side Management technologies for new buildings (religion places/schools/offices).
7. The requirements of decision making model for Demand Side Management selection.

Pilot interview (phase one)

Before conducting the full face-to-face interviews, a pilot interview was designed and conducted with a selected number of experts. As Silverman (2002) points out: “The purpose of sampling is usually to study a representative subsection of a precisely defined population in order to make inferences about the whole population”. Sampling was used to select the energy experts from each group of stakeholders to participate in this sample study. Selection of experts in sample study was based on their reputation, knowledge, and experience in energy management in Kuwait.

Due to time limitations, only five in-depth interviews were conducted with experts from all stakeholders, including two academics, one owner, one consultant, and one contractor.

Although interviews represent an effective method for collecting in depth information through direct verbal interaction between the interviewer and the respondents, in this case they proved time-consuming and rather ineffective. Each interview lasted from one to two hours although there were only seven questions involved. The experts were asked a series of open-ended questions about Demand Side Management technologies suitable for existing and newly selected buildings. They were also asked about the criteria suitable in selection of Demand Side Management technologies in the selected buildings. Finally, Experts were asked about the barriers for demand management in Kuwait and the need for method or approach for selection Demand Side Management technologies in buildings.

The lengthy duration of each interview (an average 90 minutes) due to the open-ended nature of each question led to the conclusion that future interviews will be very time consuming and ineffective. It was recommended to design a semi-filled questionnaire to allow the experts to add any options that they considered effective. This allowed for an open, flexible answer space and ensured that the field of data needed was not very narrowed.

In order to determine the relevant energy experts, their requirements, the related evaluating criteria and DSM technologies stated in the design of the semi-structured questionnaire, the following criteria were taken into consideration:

- DSM technologies and criteria identified in literature review
- Pilot literature review findings
- Kuwait's local experience in demand management
- The author's perception of the research problem

All the above items in addition to the knowledge and support of the supervisors helped in refining the preparation of the questionnaire. Therefore, a survey (semi-structured questionnaire) was designed to collect information from energy experts in the building energy management. The lists of energy experts were selected as explained in section 4.5. The experts were asked to answer the questions from the perspective of their group classification: Academics, Consultant, Contactors, and Owners.

A draft questionnaire was developed after the initial data collected from the pilot face to face interview and by utilising the output of the comprehensive literature review. This draft questionnaire was refined after a review by 5 energy experts. The semi-structured questionnaires were then expanded according to the list of criteria and DSM alternatives that had been developed from the literature review (the semi-filled questionnaire is illustrated in appendix A).

For each type of governmental buildings, the semi-filled questionnaire consists of two sections: the first section includes general information related to the participant (e.g. name, title, address, and so on) and the second section is the questionnaire content, including four questions, two mandatory and two optional. The mandatory questions are focused on the selection of DSM alternatives and criteria, while the two optional questions are aiming to investigate the existence of any decision making models dealing with DSM and the barriers that may hinder its promotion and implementation.

This qualitative approach was employed with the objective to acquire richer data from the experts. The acquisition of this set of data enabled the researcher to construct a more effective research instrument for research phase two Delphi process.

Research Phase one (modified): semi-structured questionnaire

A survey was conducted to determine the key factors in the decision making process, DSM technologies and criteria. The survey had several goals: one was the identification of those criteria that have an influence on decision making (i.e. the selection the optimal Demand Side Management technologies in buildings); another was to make sure that the researcher's bias was addressed in terms of the identification of proposed DSM technologies and criteria during the design of questionnaire. The last goal concerned the involvement of energy experts in decision making process from the beginning by identifying the problem dimensions. Specific questions within the questionnaire were designed to meet the main research objectives which are the identification of Demand Side Management technologies and criteria. The current supervisors in this research assisted in the questionnaire development, as well.

All the targeted respondents were contacted by telephone to make sure they were willing to participate in this study; further telephone follow-ups were took place until respondents sent the questionnaires back.

The semi-structured questionnaire was designed to meet the research objectives in general as well as the objectives of this phase and the identification of the proposed Demand Side Management alternatives and criteria. Before sending the questionnaire to the experts, it was pilot-tested to ensure the validity and reliability of the questionnaire. The questionnaire contained seven questions. The majority of the questions were designed as closed type with sufficient space provided for the respondents to give additional information to capture certain knowledge.

The first part consists of six sections (three for new and three for existing buildings), each includes a list of potential DSM technology options, and a basic question asked from each expert. An example of this is as follows:

"Please select the Demand Side Management technologies that is suitable for existing/new buildings below and add what you think is suitable."

The DSM technologies included in each questionnaire cover three main issues, which have the highest impact on power and energy demand in the building:

- Air conditioning systems
- Lighting systems
- Building envelope

The second part of semi-structured questionnaires consists of two sections which address criteria selection. The basic question given in each questionnaire is:

"Please determine the criteria to be considered when selecting Demand Side Management technologies for new buildings and add what you think is suitable."

Pilot survey (phase one)

In order to confirm the clarity and appropriateness of the questionnaire's design and contents and to meet the objective of this phase (the identification of criteria and alternatives for Demand Side Management in buildings), a pilot questionnaire was adopted. Specific experts from each group were selected from the expert list. The sample covered all groups (2 academics, 1 owner, 1 consultant and 1 contractors).

These samples kept the overall survey manageable and met the questionnaire's objectives. These pilot tests resulted in minor clarifications in questions, the questionnaire's sections and a change in format (secured word documents). Modifications were made based on the recommendation and feedbacks from the respondents in the pilot test.

4.6 Delphi Process

Identification of proper criteria provides a basis for the development of DSM assessment model in buildings. The research needs to select the criteria and DSM technologies in order to start the conceptual establishment of the model to effectively assess the DSM technologies selection in governmental buildings. As a result of the literature review in the previous chapter, there is a long list of criteria and DSM technologies that could be used for DSM technologies evaluation, but it is not possible to identify whether or not these criteria or specific DSM technologies are suitable for the evaluation of DSM in governmental buildings in Kuwait. Therefore, this study has utilized Delphi as an approach to select the candidate's criteria and DSM technologies as the first procedure for screening as well as the Analytic Hierarchy Process (AHP) for determining the criteria and DSM technologies' priorities and weighing system.

In this study we use Delphi technique to narrow and identify priorities for DSM alternatives and criteria assessed through data collection. The Delphi technique is an accepted method, widely used for gathering information from experts within their domain of expertise (Linstone and Turoff, 1975; Ziglio, 1996). This method was selected as a screening method to narrow down the long list of DSM alternatives and criteria that were achieved in phase one.

4.6.1 Panel selection

The success of a Delphi survey is largely dependent on the quality of participants (Dalkey and Helmer, 1963; Delbecq et al. 1971). Dalkey and Helmer (1963) reported specific criteria for the selection of panel experts. The first is that the experts exhibit a high degree of knowledge and experience in the subject matter. Another is that they exhibit "representativeness" of the profession so that their suggestions may be adaptable to the population. (See section 4.5 for further details).

In the Delphi process, the method try to maintain three principle components: anonymity, structured information flow, and controlled feedback.

4.6.2 Delphi Questionnaires (Phase two)

In Delphi procedure, the participants on the expert panel respond to a series of questionnaires (2 rounds) to achieve consensus in defining and screening the Demand Side Management alternatives and criteria achieved from phase one.

A structured Delphi questionnaire is designed based on a nine-point Likert scale for each type of building (schools, religion places, and office buildings). To determine the level of importance of each DSM option and criterion, the questionnaires provide the participants with the following basic questions:

- "Please determine the importance of Demand Side Management alternatives for existing buildings below:"

a) Existing religion places
b) Existing schools
c) Existing office buildings

- "Please determine the importance of Demand Side Management alternatives for new buildings below:"

a) New religion places
b) New schools
c) New office buildings

Table 4.6 Typical title of Delphi questionnaire for DSM alternatives

	DSM alternatives	**The importance of DSM alternatives**								
#		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Very unimportant		Unimportant		Normal		Important		Very important

Each of the above questions is attached with a list of alternatives. It is noteworthy that the alternatives for existing buildings differ from those of the new buildings, according to results from phase 1 (semi-filled questionnaire). For example, some DSM technologies, such as wall and roof insulation or thermal storage are suitable for new buildings, while it is not practical for existing buildings. The same case applies for criteria evaluation below:

- " Please determine the importance of criteria that affect the selection of Demand Side Management alternatives for existing buildings below:”

    a) Existing religion places
    b) Existing schools
    c) Existing office buildings

- " Please determine the importance of criteria that affect the selection of Demand Side Management alternatives for new buildings below:”

    a) New religion places
    b) New schools
    c) New office buildings.

Table 4.7 Typical title of Delphi questionnaire for DSM criteria

#	**Criteria**	**The importance of Criteria**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Very unimportant		Unimportant		Normal		Important		Very important

A sample of the Delphi questionnaire format used to identify the importance of criteria is shown appendix B.

4.7 Multi Criteria Decision Making Model

Decision makers are typically required to consider multiple, often conflicting objectives in making decisions. Multi criteria decision making (MCDM) is suitable for handling such decision-making problems. The evaluation and ranking of DSM alternatives is a multi-criteria (or attribute) decision making problem characterized by a set number of decision alternatives and a limited number of criteria

The MCDM models have been applied to a wide range of utility decision making problems including: evaluation of energy efficiency alternatives (Ramnathan and Ganesh, 1995), integrated resource planning (Mills et al., 1998), evaluation of resource portfolios and capacity expansion planning (Clarke, 1994 and Hobbs, 1994), evaluation of different DSM alternatives for a utility (Hobbs and Horn, 1997), and evaluation of different GHG control strategies (Ramnathan, 2003).

The literature review conducted in Chapter 3 indicated that a large number of methods have been proposed to solve MCDM problems and that different computational methods were developed for their application. However, only some of these methods were able to deal with the problem adequately. The method that is going to be used for solving the MCDM problem of evaluation and ranking of DSM alternatives in this study is the analytic hierarch process (AHP).

4.7.1 Analytic Hierarchy Process

The AHP provides a logical and systematic approach for making better decisions in complex multi criteria decision situations, characterized by conflicting objectives, uncertainty and different perspectives (Saaty, 1990). The main reasons behind the selection of AHP model are:

- AHP organizes thought in logical steps using a hierarchy and enters judgments according to understanding and experience.
- AHP has all the capabilities required to address the specific aspects which are encountered in DSM identification and ranking process.

- It employs relatively simple and straight-forward method for change and flexibility.
- The AHP approach tolerates uncertainty and allow for revision so that individuals and groups can grapple with all their concerns.
- Through the AHP hierarchy, problems are broken down into smaller parts for simple pair-wise comparisons in order to arrive at overall priorities for the alternatives in action.

The construction of the AHP pair-wise comparisons are carried out based on especially designed questionnaires. In each questionnaire, experts are asked to compare the relative importance of each criterion when selecting an alternative to meet the final goal of optimum DSM-portfolio. They are also asked to determine the preferred technology with respect to each individual criterion. The scale of relative importance for pair wise comparison, developed by Saaty (1990), is shown in Table 4.8. A sample of the AHP questionnaire is also available in appendix C.

The AHP questionnaire contains two parts, one for indicating the preference among criteria and the second for the comparison among DSM alternatives. The illustrated questions are repeated for other types of buildings and criteria of judgment.

Table 4.8 Pair-wise Comparison Scale for AHP Preferences

Numerical rating	**Verbal judgments of preferences**
9	Extremely preferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderately
1	Equally preferred

Example: Below is the blank answer sheet in which the relative importance between parameters A and B is compared.

Table 4.9 Details of the ranking of selection importance. Comparing options A and B.

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	← (A) More important									(B) More important →								
A	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	B

If you think that factor A is <u>strongly more important</u> than B, with respect to the objective, then you will mark the answer sheet as shown below.

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	← (A) More important									(B) More important →								
A	9 ☐	8 ☐	7 ☐	6 ☐	5 ☒	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	B

Based on the response of experts, the researcher constructed a set of pair-wise comparison matrices (size *n x n*) by using Microsoft Excel to show the preferences or priorities for DSM alternatives in terms of how they contribute to each criterion. The matrices are repeated for each expert.

The second step after the construction of all matrices is to synthesize each pair-wise matrix. Synthesizing is carried by dividing each element of the matrix by its column total.

4.7.2 AHP Consistency:

During the pair wise comparison, discrepancies might occur between the result of the comparison and the decision. The inconsistency ratio in AHP is a measure of how consistent we have been in our judgment. Thus, we have to determine the consistency by using the Eigen value, λ_{max}, and calculate the consistency index CI, as follows:

$$CI = (\lambda_{max} - n)/ n - 1$$

Here '*n*': is the matrix size.

This value is compared with the same index obtained as an average over large number of reciprocal matrices of the same order whose entries are random. If the ratio (called the consistency ratio CR) of CI to that from random matrices is significantly small (specified by Saaty (1995) to be no more than 10%), the level of consistency is acceptable. If the CR is greater than 0.1, the judgment matrix should be considered inconsistent. In this case, we attempt to improve consistency by reviewing and repeating the judgments. Table 4.10 (Saaty, 1995) shows the appropriate values of average random consistency.

Table 4.10 Average random consistency (RI) (Saaty, 1995)

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The value of CR is acceptable if it does not exceed 0.1. If it is more than 0.1, the judgment matrix is inconsistence, and the judgment should be reviewed and improved. This is one of the advantages of AHP method that indicates the ability to test the consistency of the judgment in advance before taking the decision. The previous steps of AHP process have to be performed for all levels of the hierarchy.

4.7.3 Sensitivity Analysis

Most of the multi criteria decision making problems encounter subjective values. The weights of the criteria and the scoring values of the alternatives against the subjective (judgmental) criteria always encounter uncertainties. In such cases, it is important to raise the following question:

"How are the ranking values of the alternatives sensitive to the changes of some input parameters of the decision model?"

The simplest case is when the value of the weight of a single criterion is allowed to vary. For additive MCDM models, the ranking values of the alternatives are simple linear functions of this linear variable and simple graphical tools can be applied to present a simple sensitivity analysis to a user (Forman and Selly, 2001).

Sensitivity analysis was not implemented in this study due to the complexity of the analysis which will would have impacted the research schedule. However, examining the sensitivity of the DSM alternatives in terms of lower level criteria and how this may affect the final decision is recommended for future research.

4.7.4 Validation of the AHP model:

The developed excel spread sheet model was validated using secondary data from three sources, mainly Charania *et al.* (2001), Vashishthaa and Ramachandranb (2006), Metty and Beckwith (2002). To validate the model, the results obtained using the developed model were compared with those obtained in the above studies and were found consistent with them. These results can be seen in Table 4.11, Table 4.12 and Table 4.13. The results indicate that the mathematics used in the proposed AHP model is able to produce consistent results and hence can be trusted to be used in analysing the data used in this work.

Table 4.11 Validation of the AHP model with the help of comparison of its results with those of Charania et al. (2001)

Technology	Case Study Results	Validation Results
Long-Life High T/W Engine	0.314	0.314436
Airframe MMC	0.151	0.150824
Self-Healing TPS	0.399	0.398663
Densifiied Hydrogen Propellants	0.037	0.036582
Graphite Epoxy Propellant Tank	0.099	0.099495

Table 4.12 Validation of the AHP model with the help of comparison of its results with those of Metty and Beckwith (2002)

Strategy	**UTILITY INDUSTRY**		**ENVIRONMENTAL ORGANIZATION**		**GOVERNMENT AGENCY**	
	Case Study Results	Validation Results	Case Study Results	Validation Results	Case Study Results	Validation Results
MACT numerical standard	0.124	0.1241	0.251	0.251	0.242	0.24138
MACT + tech. Regulation	0.049	0.04902	0.132	0.13286	0.097	0.09671
Numerical +trading	0.145	0.1449	0.094	0.09372	0.206	0.20561
Multi-pollutant	0.176	0.17631	0.324	0.32317	0.267	0.26767
Receptor-based	0.113	0.11294	0.079	0.07885	0.097	0.09683
Risk-based Standard	0.392	0.39226	0.119	0.11975	0.091	0.09081

Table 4.13 Validation of the AHP model with the help of comparison of its results with those of Vashishthaa and Ramachandranb (2006)

DSM Strategy	Utility group		Regulatory group		Consumer group	
	Case Study Results	Validation Results	Case Study Results	Validation Results	Case Study Results	Validation Results
Dedicated funds	0.138	0.13884	0.119	0.1198	0.169	0.16705
Public benefit charges	0.127	0.12687	0.13	0.13139	0.121	0.11902
Revenue regulation	0.120	0.12087	0.125	0.12225	0.115	0.11415
Technical support	0.134	0.13288	0.169	0.16714	0.141	0.14017
Obligation to perform DSM	0.121	0.11988	0.155	0.15259	0.121	0.12016
Tax exemption and incentives	0.125	0.12484	0.132	0.13182	0.112	0.11108
Promoting through industry associations	0.119	0.1199	0.105	0.10622	0.119	0.11712
Promoting through energy service companies (ESCOs)	0.115	0.11491	0.066	0.0678	0.114	0.11225

4.7.5 Fuzzy AHP

The major defect in the traditional AHP is its inability of handling the uncertainty and vagueness involved in the mapping human judgments. Many researchers who have studied fuzzy-AHP provided evidence that it shows more efficiency in handling human judgments than classical AHP method (Buckley et al., 1985; Chang, 1996; and Lootsma, 1997).

The theory of fuzzy sets has extended traditional mathematical decision theories so that it can cope well with any vagueness, uncertainty and/or imprecision problems, which cannot adequately be treated by probability distribution (Murphy, 1995). In addition, the concept of fuzzy sets provides a better model to quantify or evaluate weights when human perception is involved.

In recent years, it has been observed that due to confusion in decision makers' mind, probable deviations should be integrated to the decision making process (Askin, 2007). An important aspect predicted from all researchers is that they used the Triangular Fuzzy Number (TFN) to represent vague data or linguistic information. The major difficulty with conventional AHP is its consistency. The inconsistency is due to the transitivity property involved in the pair-wise comparisons. In the present research study, fuzzy AHP approach is tested in a traditional AHP, in which the problem of uncertainty and vagueness in the conventional AHP is solved by using triangular fuzzy numbers (TFN) in the pair-wise comparison process. This is done by using fuzzy linguistic scale ranging from 0 to 10. For consistency, the reciprocal fuzzy numbers are removed from the pair-wise comparison matrix by using triangular fuzzy numbers, corresponding to each linguistic variables used in the scale (Mahdi and Farzad, 2008). The TFNs corresponding to different verbal judgments are shown in Table 4.14.

To reflect the pessimistic, most likely, and the optimistic decision making environments, triangular fuzzy numbers with minimum value, most plausible value and maximum value were considered.

Table 4.14 The numerical scale of relative judgment proposed by Saaty

Numerical Value	**Linguistic Definition**	**Explanation**	**Fuzzy Number Scale**
1	Equal importance	Two activities contribute equally to the objective	(1,1,1)
3	Moderate importance	Experience and judgment slightly favour one activity over another	(2,3,4)
5	Strong importance	Experience and judgment strongly favour one activity over another	(4,5,6)
7	Demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice	(6,7,8)
9	Extreme importance	The evidence favouring one activity over another is the highest possible order of affirmation	(8,9,10)
2,4,6,8	Intermediate values	To reflect the compromise between the two adjacent judgments	(1,2,3), (3,4,5), (5,6,7), (7,8,9)

After the decision problem is structured into three level hierarchies, including the overall goal, evaluation criteria and DSM alternatives, the decision hierarchy is analysed and approved; therefore after traditional AHP implemented Fuzzy AHP approach will be tested, the Fuzzy AHP calculations are carried out including the following steps:

1. Assigning weights to criteria and alternatives via fuzzy AHP
2. Approving the weights which were used
3. Ranking the alternatives, and choosing the highest priority DSM alternative.

For Fuzzy AHP, a Visual Basic based application used by Ibrahim et al (2011), was employed. The application starts with the crisp data of AHP as a condition to proceed for the Fuzzy AHP results. The results obtained by this application, at the first stage, are consistent with the results obtained using the AHP Excel model used in this research.

4.8 Conclusion

The present research study assesses and evaluates the potential DSM technology measures that could be applied in the governmental buildings in Kuwait. Three types of governmental buildings are considered in the study: schools, religious places and office buildings, representing the major consumers in the sector. The methodology utilized in this research involves three instruments:

The first instrument, data collection, represents the pre-screening phase of the research study. The second instrument is employed for screening the identified DSM options and criteria for their evaluation. The Delphi process is used for this purpose. The third instrument applies the analytic hierarchy process to evaluate the DSM alternative and puts them in a prioritised order.

Three methods are used for data collection: literature review, face-to-face interviews, supported by structured semi-filled questionnaires, and reviewing the local efforts in energy management, particularly by the Kuwait Institute for Scientific Research.

To perform the Delphi process in an effective way, a dedicated questionnaire is designed and experts are chosen having a wide range of experience in energy management and DSM. The panel of experts consists of consultants, contractors, owners and academics.

The analytic hierarchy process is the decision making model used for generating criteria weights for the evaluation of DSM alternatives. The proposed Fuzzy-AHP approach is found to be able to deal with vagueness using fuzzy triangular numbers in collection human judgment through linguistic variables.

The basic contribution of this research work is to provide decision makers with a systematic approach for the selection of appropriate Demand Side Management alternatives for governmental buildings allowing multiple criteria and also to provide them with a high priority list of DSM technology options applicable in governmental buildings. This will facilitate the design and implementation of future DSM/IRP programs.

Chapter 5. *SELECTION OF DSM OPTIONS FOR GOVERNMENTAL BUILDINGS*

5.1 Introduction

Buildings account for, at least, 40 per cent of energy use in most countries. The building construction sector in Kuwait is witnessing a fast growth. The primary forces driving this growth include: growing population, increased demand for housing and increased governmental spending.

In many countries, governmental buildings are considered as part of commercial buildings. In Kuwait, governmental buildings include a wide range of buildings owned by the government, such as ministries, religious facilities, schools, institutes, offices, and so on.

In literature, the experience of many countries has shown that a wide range of DSM technology options can be implemented in the building sector. The selection of cost-effective and reliable technologies is a complex problem which depends on many factors, such as type of the building, climatic conditions, construction, and energy performance among others.

The aim of this chapter is to identify the potential DSM technology options and their criteria of judgment in the governmental buildings through expert's decision-making techniques. The list of DSM options developed at the end of this chapter is an essential pre-requisite step for the selected MCDM model.

The next section presents an overview of the energy efficiency performance of the governmental buildings in Kuwait, with specific emphasis on the more energy consuming types, such as schools, religious buildings, and office buildings.

Section 5.3 describes the procedure and results of the pre-screening methods used to develop a detailed DSM portfolio and criteria measures. Section 5.4 describes the screening process through Delphi technique, including designing the questionnaire, group response and final results. Section 5.5 describes the Delphi method results and section 5.6 the

Analysis of Delphi Results. The chapter is ended by the hierarchy configuration of the AHP based on the final number of DSM alternatives and criteria resulted from Delphi process.

5.2 An Overview of Governmental Buildings Energy Performance

Governmental buildings in Kuwait are part of institutional buildings and include various types of buildings, such as schools, religious buildings, clinics, office buildings, libraries, post offices and the like. Up-to-date information on the share of governmental buildings' electricity consumption with respect to total consumption is not available. However, earlier estimates of the MEW indicate that, at least, 11% of the total end-use electricity consumption is used by governmental buildings. Based on the year 2010, this share of consumption may have reached 4858 GWh.

This research study focuses on three types of governmental buildings: schools, religious places and office buildings. These buildings have a high share of consumption among the sector. The research results could be easily applied for other buildings of similar performance.

5.2.1 Kuwait Energy Efficiency Building Code (The Code of Practice)

The Code of Practice for energy efficiency was introduced by MEW in 1983. It defines basic standards for peak loads applicable to residential, commercial and institutional buildings. The Code puts limits on:

- The maximum power density (W/m^2) for various types of buildings and A/C systems
- The maximum power density (W/m^2) for internal lighting for various types of buildings
- The maximum load (kW/ton) for various types of A/C equipment and systems
- The minimum power factor for certain equipment and appliances
- The maximum overall U-value (thermal conductivity) for walls and roofs

In addition to the mandatory rules, the Code provide recommendations for energy efficiency improvement and conservation measures, including the use of efficient lighting and appliances, the use of shading devices, improved building design, the use of efficient A/C systems, the use of load control and energy management devices, the use of energy recovery systems and the use of variable air volume devices.

The regulations with respect to insulation, glazing and building colours were estimated to achieve a reduction in cooling load of up to 60% for new residential and commercial buildings. The actual effect of the introduction of the building codes on the growth of the system peak has not been measured yet.

Provided that these regulations were strictly enforced, there are still some potentials left for efficient building. There is, however, evidence that the regulations are not strictly adhered to it. Stricter monitoring for the implementation of new buildings could, therefore, improve the energy balance and lead to overall peak demand reduction.

The Code of Practice specifies the basic energy conservation requirements for the specific types of buildings considered in our research study as given in Table 5.1.

Table 5.1 The Code Limits for Governmental Buildings

Parameter	Religious Places	Schools (Classrooms)	Office Buildings
Peak Watt/m^2 for A/C	120 Watt/m^2 for air-cooled	100 Watt/m^2 for air-cooled	70 Watt/m^2 for air-cooled
Peak Watt/m^2 for A/C	80 Watt/m^2 for water-cooled	65 Watt/m^2 for water-cooled	50 Watt/m^2 for water-cooled
Peak Watt/m^2 for lighting	30 Watt/m^2	30 Watt/m^2	30 Watt/m^2

The Code also specifies the minimum efficiency required for A/C systems as follows:

- The power utilisation factor (PUF) of air-cooled systems shall not exceed 2kW/Ton under Kuwait peak design conditions, including compressors, fans and all electrically driven equipment.
- The PUF of water-cooled systems shall not exceed 1.4 kW/Ton, including compressors, fans and all electrically driven equipment.

Although the required standards should have led to a reduction in cooling load by up to 60% in new buildings, the growth in peak load did not show any significant slowdown after the introduction of the building codes. One reason might be that the codes have not been adhered to by end users. The enforcement of the code is mainly in the responsibility of the Ministry of Electricity and Water (MEW); MEW is responsible for the approval of Watt/m2 calculation for A/C and lighting, the approval of all electrical drawings, all energy conservation measures and the approval of kW/ton for air conditioning systems and equipment.

The minimum value of power factor is also specified in the Code of Practice for various types of end-use equipment, such as 0.8 for single phase motors at full load, more than 0.83 and up to 0.89 for three phase motors, and 0.9 for fluorescent and discharge lamps.

5.2.2 Baseline Performance of Governmental Buildings

The behaviour of any building with respect to energy consumption and potential efficiency improvements depends on many factors, including size, construction, orientation, climatic conditions, and so on. Each of the selected three types of governmental buildings has its own typical features which will affect its energy performance and hence could lead to different approaches with respect to potential DSM technology measures.

To obtain a more effective decision making process and the better selection of the potential DSM technology options, it is important to have a general background on the energy performance baseline of the relevant governmental buildings. Construction parameters and important features, related to energy performance, of the three buildings are given below.

5.2.2.1 Religious buildings

Most religious buildings have certain aspects in common with each other; as with other regions, Kuwaiti Islamic architecture reflects the local architecture in its style. A religious building usually consists of a large praying hall for men and a smaller room for women. A religious building differs in construction with typical residential villas in three fundamental factors (MOE, Energy Conservation Program, 2004):

- It consists mainly of a very large air-conditioned room with a high ceiling.
- Two wall constructions are used, one made of plaster, cement block and bricks, the other of plaster and cement blocks only.
- Internal loads are very high only during certain hours of the day (praying hours partially occupied).

Based on a typical model of religious building architecture provided by the MEW through the Energy Conservation Program designed for the Code of Practice No. MEW/R – 6, the base case building parameters are assumed as follows:

Construction Parameters:

- Religious building Shape: a square main praying room with a large dome on top and an elevated women's praying room.
- Floor area : 325.0 m^2
- Living space area : 431.0 m^2
- Gross wall area : 720.8 m^2
- Roof area : 453.0 m^2
- Widows area : 65.5 m^2 (9.25% of wall area)
- Conditioned volume : 2450.0 m^3
- Glass type : single pane clear glass
- Wall U-value : 0.28 Btu/h. ft^2. ^{o} F (main walls)
- Wall U-value & : 0.92 Btu/h. ft^2. ^{o} F (women's praying room dome)
- Roof U-value : 0.59 Btu/h. ft^2. ^{o} F (main praying room)
- Roof U-value : 0.89 Btu/h. ft^2. ^{o} F (dome)
- Roof U-value : .75 Btu/h. ft^2. ^{o} F (women's praying room)

Major Loads:

- Air conditioning: package single zone system in the main praying room
- Peak load is estimated at 2/kW per ton of A/C.
- Lighting system: 1.56 W/ft2 incandescent type

- Equipment load: none
- Ventilation: because of frequent door opening, a ventilation rate of 1 air change/hr. at nominal 7.5 mph wind speed was selected. This corresponds to 5 CFM/person.

Number of people & occupancy:

- Number of people: up to 300 in main room, 30 in women's room
- Occupancy: every Friday, during mid-day praying, the occupancy is very high and it may reach 100%. In addition, the occupancy is increased during the holy month of Ramadan, making a high burden on lighting and air conditioning systems.

5.2.2.2 School buildings

The total number of schools in Kuwait is about 1145. Out of this total, 664 are public and 481 are private schools (Kuwait Educational Indicators, Report 2007). Two-thirds of all students (from kindergarten to secondary) were in public schools during the year ending 2006. In general, schools are classified into four types: preschools, elementary, intermediate and high schools.

A school building is a simple two storied, squared construction with classrooms on the periphery and a hall in the centre. This type of school would allow day-lighting, natural ventilation and is more suitable for energy conservation. The corridors of the school are considered unconditioned spaces, and only the cool air escaping from the conditioned areas brings freshness into them.

The typical base case parameters of this school are summarised below:

Construction Parameters:

Number of classrooms	:	24
Floor area	:	2836.9 m^2
Living space area	:	5257.7 m^2

Gross wall area	:	1572.9 m^2
Roof area	:	3173.5 m^2
Widows area	:	367.4 m^2 (23.4 of wall area)
Conditioned area	:	2851.3 m^2
Glass type	:	single pane clear glass
Wall U-value	:	0.48 Btu/h. ft^2. ^{o} F
Roof U-value	:	0.21 Btu/h. ft^2. ^{o} F

Major Loads:

Air conditioning system: package single zone system in the main hall room. Peak load of 2 kW /ton of air conditioning, windows air units in each classroom and office, 2 kW/ton.

Lighting system: 2.0 W/ft^2, fluorescent type

Equipment load: offices 2 kW load each, main hall 3 kW.

Ventilation: 1 a.c/hr. at nominal 7.5 mph wind speed. Additional 7.5 cfm/through A/C. system for main hall when operating.

Number of people & occupancy:

Number of people: up to 600 in main hall and 28 in each classroom (not simultaneously).

Number of students: 672

Occupancy: the classroom is usually full during normal days. Saturdays and Fridays are off.

5.2.2.3 Office buildings

Governmental office buildings include ministries, organizations, government institutions and other office buildings related to the government.

The base case office building considered below consists of two large four-storey buildings, with the following parameters:

Construction Parameters:

Floor area : 2148.4 m^2

Living space area : 8590.0 m^2

Wall area : 5056.5 m^2

Roof area : 3173.5 m^2

Widows area : 1302.4 m^2 (23.4 of wall area)

Glass type : single pane clear glass with heavy shading due to recess.

Wall U-value : 0.303 Btu/h. ft^2. ^{o} F

Roof U-value : 0.187 Btu/h. ft^2. ^{o} F

Major Loads:

Air conditioning system : Two water-cooled chillers (cooling tower), two pipe fan coil air-handling units. 1.4 kW per ton at peak load.

Lighting system : Fluorescent lamps 3.0 W/ft2.

Equipment load : 10 kW per floor per building at maximum load operating.

Number of people & occupancy:

Number of people : 130 per floor per building at maximum occupancy.

Occupancy : It is assumed that office buildings are fully occupied during weekday and empty during the weekend (Fridays and Saturday).

5.2.3 Potential Energy Efficiency Improvement

The amount of energy efficiency potential in a building depends on the quantity and efficiency of the end uses, such as lighting and cooling. In Kuwait, like the rest of arid-zone countries, the climate is hostile. The summer season extends from six to seven months and ambient temperature often reaches 50 ^{o}C. Thus, cooling is essential for all types of buildings. Consequently, air conditioning (A/C) systems are the largest consuming loads in summer, and account for more than 70% of the national peak demand and about 45% of the annual electricity consumption (Al-Marafie et al., 1989).

In addition to weather conditions, the efficiency of the building envelope and behaviour of the occupants are also important factors in determining the potential of energy and demand savings.

In this section the energy performances of the previously mentioned buildings are analysed with respect to the potential DSM savings. The procedure is to compare the energy efficiency indicators of the present buildings with the worldwide best practices, taking into consideration the specific climatic conditions of Kuwait.

Before analysing the energy performance of the buildings under consideration, we introduce the main parameters of the energy efficiency building code, or the Code of Practice, applied in Kuwait since the early 80's.

The annual energy consumption and peak load for the base case buildings described above are summarised in Table 5.2. Two energy efficiency indicators are also shown in the table and expressed by: Energy intensity (EI), defined as the energy consumed per unit area (kWh/m^2 per yr.), and/or Peak power density (PD), defined as the amount of peak load per unit area (kW/m^2).

A comparison between the three types of buildings with respect to annual A/C and total peak loads is illustrated in Figure 5.1. It is clear from the figure that the air conditioning peak load shares the majority of consumption in the religious buildings, representing 93%, followed by school (62%) and office building (51%).

As shown in Table 5.2, the annual consumption of office buildings is approximately four times that of the religious buildings, however, the energy intensity of religious buildings is much higher than that of the office building. This is due to the extensive use of A/C and lighting systems.

Table 5.2 Annual Energy Consumption and Peak Load for Base Case

Building	A/C		Overall Building			
	PL	PD	EC	EI	PL	PD
	kW	W/ m^2	MWh	kWh/m^2	kW	W/ m^2
Religious building(1)	116	269.0	416.3	965.2	124.4	288.8
School building(2)	226	109.4	213	74.6	367.2	128.8
Office building(3)	463.4	53.9	3033.0	353.1	900.8	104.8

PL = Peak load, PD = Power density, EC = Energy consumption, EI = Energy intensity

(1) Peak at 4 P.M. on July 3, (2) Peak at 1 P.M. on Sept. 7, (3) Peak at 4:30 P.M. on July 28

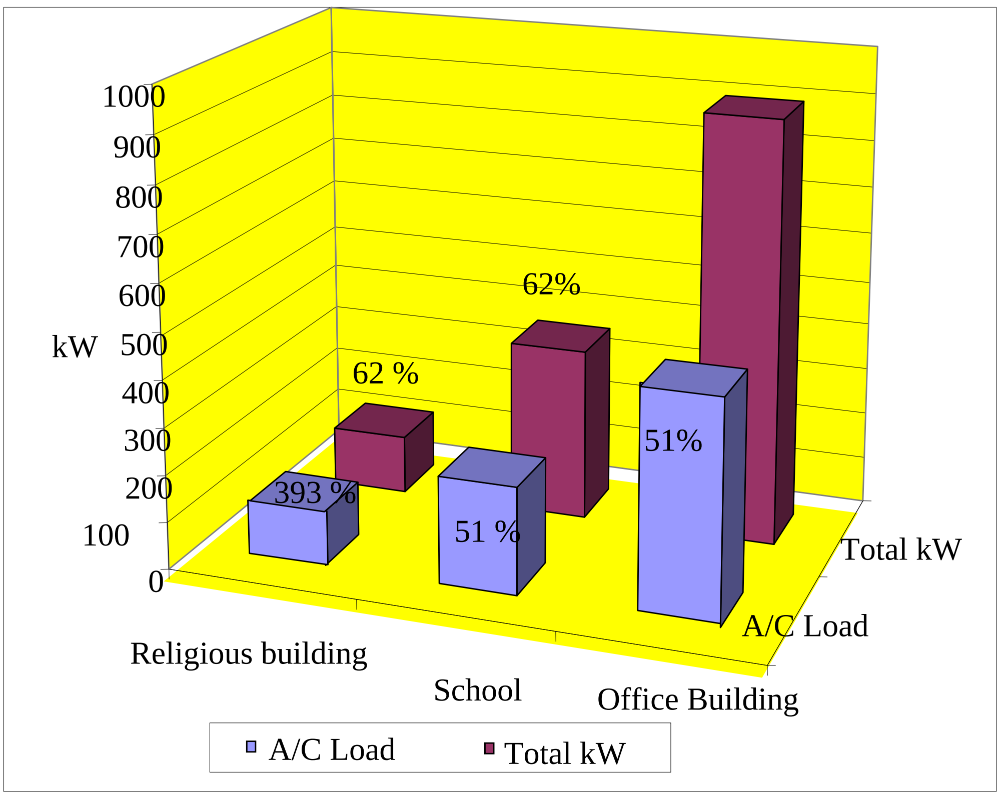


Figure 5.1 Power Consumption in Governmental Buildings (MEW, 2004)

Assuming that water-cooled chillers are used in the three buildings, we compare the above figures of energy efficiency indicators with the maximum limits of the Code of Practice. The potential of energy efficiency improvement can be estimated at approximately 62% for religious buildings, 13% for schools and 24% for office buildings. These results are based on the level of power density (W/ m^2). Of course, the limits set by the Code of practice, are old and have to be reconsidered, since the development of energy efficient A/C equipment, and high efficiency lighting systems, such as CFLs and LEDs are now available in the market.

5.3 Identification of DSM Technologies portfolio

The aim of this process is to gather information on the potential DSM technology measures available by local studies, audits, and projects implemented in Kuwait. At the end of this process, it is important to set a portfolio of potential DSM alternatives in governmental buildings. The preliminary list resulting from this process should be suitable for governmental buildings in Kuwait, and represent a suitable background for further screening through Delphi process and more evaluation through decision making techniques by using Analytic Hierarchy Process and Fuzzy Analytic Hierarchy Process.

As mentioned earlier, three tools were used in this research for data collection and pre-screening of the potential DSM technology measures:

- Literature review
- Local experience
- Face-to-Face interviews

Brief descriptions of each were presented in the research methodology (Chapter 4). The following section includes a summary of the lessons learned from local studies and audits performed by local experts in Kuwait, specifically by the Kuwait Institute of Scientific Research (KISR) in governmental buildings. KISR has a long experience in energy management and is considered as the major contributor in energy management activities improvement in Kuwait.

5.3.1 Data Collection Procedure

The criteria and DSM technologies development

A field study was conducted to answer the research objectives; to identify the potentially viable DSM alternatives and to explore the criteria which influence the selection of DSM alternatives. Also the field study was conducted to determine the key factors in the decision making process of selecting the optimal demand side management technologies in governmental buildings in Kuwait by identifying the proposed demand side management technologies and criteria that could affect in the selection process.

The Selected governmental buildings for this study were:

- School.
- Religion places
- Governmental offices

Research Phase one: face-to-face interview

As explained in chapter 4, the methodology consisted of face-to-face interviews as a research instrument for phase one, (shown in Appendix A). Concerning interview content, the questions were designed to gather efficiently information on the demand management and demand side management technologies in Kuwait.

It was clear from the outcome of the pilot interviews, that the method was very time consuming and ineffective. It was recommended by some energy experts who participated in the pilot interviews to design a semi-structured questionnaire based on literature reviews and to allow the expert to add any options they considered effective.

Semi-structured questionnaire data analysis

The semi-structured questionnaires were distributed among 42 qualified experts. Only 28 experts responded: 13 academics, 7 building owners, 6 consultants and 2 contractors. Table 5.3 summaries the experts involves in Phase one.

Table 5.3 Energy experts participated in Research Phase one survey

Group	University / Institute	Department /Section	Sent	Received
Academics	Kuwait University	College of Engineering & Petroleum – Mechanical Engineering Department	4	3
Academics	Kuwait Institute for Scientific Research	Energy & Building Technologies Department	5	4
Academics	Public Authority for Applied Education and Training	Mechanical Engineering and Refrigeration Department	6	6
Owners	Public Authority of Housing	Engineering Design Department	7	3
Owners	Ministry of Religious Affairs	Engineering affairs Department	8	4
Consultants	Engineering System Groups	Engineering Design Section	5	3
Consultants	PACE Consulting Engineers	Engineering Design Section	5	3
Contractors	Kazema Global Holding	Engineering Services Section	2	2
Total			42	28

An example of the answers to semi-structured questionnaires related to the selection of DSM technologies and criteria are illustrated in Tables 5.4 and 5.5 respectively. All answers are shown in Appendix A.

Table 5.4 Results of Semi-filled Questionnaire for DSM Selection for Existing Schools.

	DSM Options	Existing Schools				
		Academics (13)	Consultants (6)	Owners (7)	Contractors (2)	Total (28)
A	Air Conditioning System:					
1	Programmable thermostat	11	6	7	2	26
2	High efficiency A/C Units	9	6	7	2	24
3	Variable frequency drives	8	6	4	1	19
4	Building Management System	5	--	1	1	7
5	Thermal energy storage	--	--	--	1	1
6	Use air curtain at entrances	3	--	--	1	4
Other Options, Selected by Experts						
7	Load control for A/C	3	1	3	1	9
8	Facility engineer	1	--	-	--	1
9	Proper Operation & Maintenance	--	--	--	1	1
10	Use of Chillers instead of packages and/or mini split units	1	--	--	1	1
B	Lighting System:					
11	High efficient lighting	10	1	5	2	18
12	Optimization of day lighting	3	1	--	1	5
13	Use of Efficient and electronic ballasts	11	4	4	2	21
14	Use timers for scheduling	4	6	5	2	17
15	After-hours override	4	--	1	2	7
16	Occupancy sensors	9	4	--	2	15

17	Timers for scheduling	12	6	5	2	17
C	Building Envelope:					
18	Highly reflective glass windows	11	6	7	2	26
19	Cladding/coating outside walls, roofs	9	6	7	2	24
20	Use double-glazed glass for windows	--	--	--	--	--
21	Insulation of walls and roofs	1	--	--	--	1

Table 5.5 Example of the semi-structured questionnaire Results (Existing Buildings). The breakup of the experts is as follows: Academics: 13, Consultants: 6, Owners: 7, Contractors: 2, Total: 28

	DSM Options	Existing Schools		Existing Religious		Existing Offices		Total Avg.
		Scores	%	Scores	%	Scores	%	%
A	Air Conditioning System:							
1	Programmable thermostat	26	92.86%	25	89.29%	26	92.86%	91.67%
2	High efficiency A/C Units	24	85.71%	24	85.71%	24	85.71%	85.71%
3	Variable frequency drives	19	67.86%	18	64.29%	25	89.29%	73.81%
4	Building Management System	7	25.00%	4	14.29%	15	53.57%	30.95%
5	Thermal energy storage	1	3.57%	1	3.57%	1	3.57%	3.57%
6	Use air curtain at entrances	4	14.29%	11	39.29%	10	35.71%	29.76%
7	Power factor correction	--	--	17	60.71%	--	--	20.24%
8	Cooling recovery unit	--	--	--	--	16	57.14%	19.05%
Other Options Selected by Experts								
9	Load control for A/C	9	32.14%	10	35.71%	8	28.57%	32.14%
10	Shading A/C units	--	--	1	3.57%	--	--	1.19%
11	Facility engineer	1	3.57%	1	3.57%	1	3.57%	3.57%
12	Proper Operation & Maintenance	1	3.57%	2	7.14%	2	7.14%	5.95%
13	Use of chillers instead of AC packages and / or mini split Units	1	3.57%	1	3.57%	--	--	2.38%
14	Tree shading for buildings			1	3.57%		--	1.19%
B	Lighting System:							

15	High efficient lighting	18	64.29%	26	92.86%	26	92.86%	83.34%
16	Optimization of day-lighting	5	17.86%	3	10.71%	13	46.43%	25.00%
17	Use of Efficient electronic ballasts	21	75.00%	8	28.57%	15	53.57%	52.38%
18	Use timers for scheduling	17	60.71%	21	75.00%	25	89.29%	75.00%
19	After-hours override	7	25.00%		0.00%	7	25.00%	16.67%
20	Occupancy sensors	15	53.57%	22	78.57%	22	78.57%	70.24%
C	Building Envelope:							
23	Highly reflective glass for windows	26	39.29%	27	96.43%	24	85.71%	73.81%
24	Cladding/coating outside walls& roofs	24	85.71%	25	89.29%	25	89.29%	88.10%
25	Use double-glazed glass for windows	--	--	1	3.57%	24	85.71%	44.64%
26	Insulation of walls and roofs	1	3.57%	1	3.57%	-	--	2.38%

Table 5.6 Answers of Experts to Semi-Structured Questionnaires for Criteria Selection of Existing Buildings. The breakup of the experts is as follows: Academics: 13, Consultants: 6, Owners: 7, Contractors: 2, Total: 28

	Criteria	**Academics**		**Consultants**		**Owners**		**Contractors**		**Total Score**
		Scores	**%**	**Scores**	**%**	**Scores**	**%**	**Scores**	**%**	**%**
C1	Flexibility for O & M	11	84.62%	6	100.00%	7	100.00%	2	100.00%	96.15%
C2	Durability and reliability	8	61.54%	4	66.67%	5	71.43%	2	100.00%	74.91%
C3	Capital Cost	8	61.54%	6	100.00%	7	100.00%	2	100.00%	90.38%
C4	Reduction in consumption	11	84.62%	6	100.00%	7	100.00%	1	50.00%	83.65%
C5	Comfort ability for users	10	76.92%	4	66.67%	4	57.14%	2	100.00%	75.18%
C6	Impact on environment (reduction of GHG emissions)	6	46.15%	6	100.00%	5	71.43%	1	50.00%	66.90%
Other Options Selected by Experts										
C7	Payback period	3	23.08%	--	0.00%	--	0.00%	-	0.00%	5.77%
C8	Technology life cycle	2	15.38%	--	0.00%	--	0.00%	--	0.00%	3.85%
C9	Ease of implementation	3	23.08%	--	0.00%	--	0.00%	1	50.00%	18.27%
C10	After sale service	--	0.00%	1	16.67%	--	0.00%	--	0.00%	4.17%

Table 5.7 Example of the semi-structured questionnaire Results (New Buildings). The breakup of the experts is as follows: Academics: 13, Consultants: 6, Owners: 7, Contractors: 2, Total: 28

	DSM Options	New Schools		New Religious		New Offices		Total Average
		Scores	%	Scores	%	Scores	%	%
A	Air Conditioning System:							
1	Programmable thermostat	23	82.1%	21	75.0%	20	71.4%	76.2%
2	High efficiency A/C Units	27	96.4%	24	85.7%	27	96.4%	92.9%
3	Variable frequency drives	19	67.9%	14	50.0%	22	78.6%	65.5%
4	Building Management System	16	57.1%	25	89.3%	27	96.4%	81.0%
5	Thermal energy storage	16	57.1%	6	21.4%	18	64.3%	47.6%
6	Use air curtain at entrances	8	28.6%	13	46.4%	12	42.9%	39.3%
7	Power factor correction		--	7	46.4%		--	15.5%
8	Cooling recovery unit		--		--	14	50.0%	16.7%
9	Central A/C with VAV boxes and/or heat pumps		--		--	8	28.6%	9.5%
Other Options Selected by Experts								
10	Load control for A/C	11	39.3%	6	21.4%	11	39.3%	33.3%
11	Shading of A/C equipment	3	10.7%	1	3.6%		--	4.8%
12	Facility engineer	1	3.6%			1	3.6%	2.4%

13	Proper Operation & Maintenance	1	3.6%			1	3.6%	2.4%
14	CO_2 sensor		--	1	3.6%		--	
15	Economizer cycle		--	1	3.6%		--	1.2%
B	Lighting System:							
16	High efficient lighting	27	96.4%	27	96.4%	26	92.9%	95.2%
17	Optimization of day-lighting	13	46.4%	3	10.7%	13	46.4%	34.5%
18	Use of Efficient electronic ballasts	18	64.3%	18	64.3%	15	53.6%	60.7%
19	Use timers for scheduling	26	92.9%	26	92.9%	24	85.7%	90.5%
20	After-hours override		--		--	7	25.0%	
21	Occupancy sensors	15	53.6%	19	67.9%	7	25.0%	48.8%
C	Building Envelope:							
23	Highly reflective glass for windows	25	89.3%	26	92.9%	25	89.3%	90.5%
24	Cladding/coating outside walls & roofs	25	89.3%	25	89.3%	27	96.4%	91.7%
25	Use double-glazed glass for windows		--		--	22	78.6%	26.2%
26	Building design and orientation		--	17	60.7%		--	20.2%

Table 5.8 Answers of Experts to for Criteria Selection of New buildings. The breakup of the experts is as follows: Academics: 13, Consultants: 6, Owners: 7, Contractors: 2, Total: 28

	Criteria	**Academics**		**Consultants**		**Owners**		**Contractors**		**Total Score**
		Scores	**%**	**Scores**	**%**	**Scores**	**%**	**Scores**	**%**	**%**
C1	Flexibility for O & M	12	92.31%	6	100.00%	7	100.00%	2	100.00%	98.08%
C2	Durability and reliability	8	61.54%	4	66.67%	6	85.71%	2	100.00%	78.48%
C3	Capital Cost	9	69.23%	6	100.00%	7	100.00%	2	100.00%	92.31%
C4	Reduction in consumption	11	84.62%	6	100.00%	7	100.00%	1	50.00%	83.65%
C5	Comfort ability for users	11	84.62%	6	100.00%	7	100.00%	2	100.00%	96.15%
C6	Impact on environment (reduction of GHG emissions)	7	53.85%	4	66.67%	5	71.43%	1	50.00%	60.49%
Other Options Selected by Experts										
C7	Payback period	3	23.08%	-	0.00%	-	0.00%	1	0.00%	5.77%
C8	Technology life cycle	1	7.69%	-	0.00%	-	0.00%		0.00%	1.92%
C9	Ease of implementation	3	23.08%	-	0.00%	-	0.00%	1	50.00%	18.27%
C10	After sale service	-	0.00%	1	16.67%	-	0.00%	-	0.00%	4.17%
C11	Availability of technology	-	0.00%	-	0.00%	1	14.29%	-	0.00%	3.57%

5.4 Analysis of Semi-structured questionnaire results

The findings of phase one (semi-structured questionnaire) were evaluated and the implications outlined. The purpose of phase one was to obtain information from carefully selected group of energy expert respondents. The findings assisted in the development of a suitable research instrument for the next phase of the research (Phase two). Phase two involved using Delphi study to conduct a tool for screening the demand side management technologies and criteria identified in phase one. Based on questionnaire results, the long list identified for each building is shown in appendix (B).

The presence of too many criteria/alternatives makes the evaluation process difficult and time-consuming. Thus, it is not practical to include all factors as they increase the number of questions in Phase two (Delphi) and increase the number of pair-wise comparisons in Phase three (AHP) as well as the related computational effort. For this reason the study considers an elimination process for non-important factors suggested in phase 1; for example, the building facility engineer is not considered a proper alternative for demand side management technologies. Results were consolidated by the researcher, duplicates were removed and the terminology was unified. The lists of alternatives were compacted by aggregating items that appeared to have high similarity and then were categorized based on knowledge from literature studies. For example many techniques aggregated by one alternative high efficient lighting system were recommended to minimize the number of alternatives.

Based on data collection through Phase 1, twenty preliminary alternatives were identified. These alternatives are subject to screening through Delphi process to be removed, in case of overlaps and conflicting objects. Table 5.9 and Table 5.10 illustrate descriptions about the proposed alternatives and criteria.

The implications of phase one results can be summarised for this phase as such:

1) Identification of critical criteria and candidates DSM technologies for governmental buildings in Kuwait and developing countries which have similar building characteristics and weather conditions.

2) Different criteria identified include technical, environmental, financial, and social factors which argue the use of single criterion evaluation and the need for evaluating DSM technologies in buildings from different attributes considerations.

3) Both qualitative and quantitative criteria identified which emphasis on the necessity to be taken in consideration for DSM selection process.

5.5 Potential DSM Technologies in Governmental Buildings

Below is a brief description of the technical features of each proposed DSM options.

Table 5.9 Description of Potential DSM Technologies in Governmental Buildings

#	DSM Technology	Description
1	Programmable Thermostat	It is a thermostat which is designed to adjust the temperature according to a series of programmed settings that take effect at different times of the day. The times for turning on the air-conditioning system, or part of it, can be adjusted according to a pre-set schedule. As a result, the equipment can be automatically switched off when the building is not occupied. Programmable thermostat can store and repeat multiple daily settings.
2	High Efficiency A/C Units	Most of the air conditioning systems in governmental buildings in Kuwait are central air conditioners (CACs) and split units. CACs are rated according to their seasonal energy efficiency ratio (SEER). This is the cooling output divided by the power input [SEER = (Btu/hr)/(W) = Btu/W.h]. The higher the SEER, the more efficient the air conditioner. The US Federal efficiency standards for CACs took effect in 1992, requiring SEER of 10. New standards (after 2006) raised the SEER requirement to minimum 13, an improvement of 30% relative to 10-SEER units. Many older CACs have SEERs of only 6 or 7 (www.energystar.gov/index.cfm). Most of A/C systems in Kuwait are oversized, which, besides raising purchase cost, leads to reduced energy efficiency, poorer humidity control and shorter product life, all due to excessive on-off cycling.
3	Variable Frequency Drives	Variable Frequency Drives (VFDs) are used in motors to maximize part load efficiency and savings, particularly for chilled water A/C systems. When centrifugal pumps, compressors, fans, and blowers are operated at constant speed (or frequency) and output is controlled by throttled valve or dampers, the motor operates at, or close to, full load all the time- regardless of the delivered output. Substantial energy is lost by these closed dampers and valves. Significant energy savings can be realized if the driven unit is operated at only the speed necessary to satisfy the demand. VFD permits optimum operation of equipment by closely matching the desired system requirements.
4	Use of Central Air-conditioning with VAV boxes	The variable air volume (VAV) air conditioning system changes the quantity of air supplied to the space in response to changes in loads. The variable air volume is achieved by VAV terminal boxes. The boxes have a modulating damper that throttles in response to the thermostat setting. When the indoor temperature

		conditions vary from the set point, the VAV box damper responds by increasing the supply air volume to the space. The supply air fans shall have their air flow rates controlled by a variable frequency drive which gets signal from the duct static pressure sensor(s). Airflow reduction brings about a corresponding reduction in fan horsepower and therefore the VAV systems are considered much more efficient. VAV systems are typically used in multi-zone application having different cooling requirements throughout the occupied area. The comfort conditions are maintained by using independent setback thermostats thereby providing the opportunity to control comfort levels in each zone.
5	Install Cooling recovery unit	An energy (cooling) recovery ventilator (ERV) is a type of mechanical equipment that features a heat exchanger combined with a ventilator system for providing controlled ventilation into a building while minimizing energy loss. Mechanical ventilators exchange air inside the building with fresh air from the outside. This helps to reduce indoor pollution levels, and greatly increases the comfort level inside the building. Besides providing controlled ventilation, ERVs are able to filter, humidify, dehumidify, heat, or cool the incoming fresh air. The most popular design of ERVs utilizes a desiccant wheel to remove both heat and a significant amount of moisture from the incoming air, which reduces the load on the air conditioning system. Most ERV systems can recover about 70% -80% of the energy in the existing air and deliver that energy to the incoming air. However, they are most cost effective in climates with extreme winters or summers, and where the fuel costs are high.
6	Install Remote Control for A/C Units	The remote monitoring and A/C control unit is usually a microprocessor-based controller applied to rooftop or self-contained air conditioning systems. It is designed to provide multiple-unit control via network communications. A variety of control capacities can be incorporated in the system, such as common-duct static pressure, common control temperature distribution and schedules, which can be individually assigned to any single unit or combination of units.
7	Shading for A/C Units	Keep the sun out the AC units by shading the AC units for harsh sun during summer could improve the efficiency of AC units. Shading A/C units may save cooling energy.
8	Install Air Curtains at Entrances	Air curtain produce high speed air barrier, dividing areas into two independent temperature zones. It is usually installed over entrance doorway. Levels of interior air conditioning are maintained, saving energy and increasing comfort. Summer heat, dust, smoke and exhaust fumes are kept out.
9	Install Sensors for Supply and Return Air Temperature	Energy efficiency improvement and better comfort could be achieved by optimizing the difference between supply and return air temperatures. This option is usually incorporated in most of the energy management systems (EMS).
10	Proper Operation and Maintenance (O & M)	Building Operation and Maintenance (O & M) is the ongoing process of sustaining the performance of building systems according to design intent, the owner's or occupants' changing needs, and optimum efficiency levels. Building maintenance programmes, specifically designed to enhance operating efficiency of air conditioning and lighting systems, can save 5 to 20% of the energy bills without significant capital investment (O & M Best Practices). Examples of regular maintenance for A/C are: cleaning of condensers and coils, changing belts, and filters, fixing duct leaks.' and checking of

		economizer operation and adequate refrigerant levels.
11	Install Thermal Energy Storage for A/C	A cool energy storage (CES) air conditioning system functions by removing heat from a thermal storage medium during periods of low cooling demand and then subsequently releasing the stored cooling at a later time to meet an air conditioning or process cooling load. Various forms of cool storage media may be used, including chilled water, ice or eutectic salt phase change material. The choice of an appropriate type and size of CES system depends upon the cooling load profile of the target building and the Time Of Use (TOU) electricity charge structure. Incorporating cool thermal storage into air conditioning systems can help the electric utilities to reduce the load during the on peak period and increase the load during the off peak period. This shifting of the load improves utilization of the base load and improve load factor. In buildings, the peak power demand for A/C is significantly reduced by allowing energy intensive electrically driven chillers to operate mostly during night time when the electricity rates and demand are lower.
12	Install High Efficiency Lighting	Lighting system may share from 20% to 30% of the total annual electricity consumption in governmental buildings, and could be more in the case of religious buildings and schools. Replacing existing traditional incandescent lamps with compact fluorescent lamps (CFLs) can save about 75% of the energy used by incandescent bulbs. Using high efficiency lighting can achieve indirect saving by reducing the A/C load
13	Install Time of Use Control	Time of use control is applied for switching off end-use equipment, especially lighting, when it is not required. Clock switches or timers and centralized controls are usually used for this purpose. This DSM option is important in countries where time of use (TOU) tariff is applied. In Kuwait the system of TOU tariff is not yet applied.
14	Install Occupancy Sensors	Occupancy sensors used, mainly for lighting control, to detect the presence of people in a space and turn light off when spaces are unoccupied. They include delays and logic systems to avoid false or too frequent turning off the light fixtures. Some sensors can be also used in conjunction with dimming controls to keep the light from turning completely off when a space is unoccupied. Occupancy sensors can also be used to enhance the efficiency of centralized controls by switching off lights in unoccupied areas during normal working hours as well as after hours.
15	Install Building Management Systems (BMS)	Energy management systems (EMS) are installed in buildings to reduce operating costs, the majority of which are energy costs. They offer a wide variety of control strategies, and the control function that tends to save the greatest amount of energy is that of stopping or reducing equipment operation during non-occupied periods. These systems monitor and control services such as lighting, chillers, boilers, etc. The simplest systems comprise dedicated controls, while the more complex comprehensive systems offer a broader range of features. By concentrating the control of many items of equipment at a single point, the EMS allows the building operator to tailor building operation to precisely satisfy occupant’s needs.
16	Install Power Factor Correction	Most of electric loads are inductive, for example, motors, transformers, fluorescent lamps, and induction furnaces. Inductive loads require two components of current: The power producing, or active, current which is converted by equipment to work,

		usually in the form of heat, light, or mechanical power. The unit of measurement of power is the Watt. The magnetizing, or reactive, current required to produce the flux necessary for the operation of electromagnetic devices. Without magnetizing current, energy could not flow through the core of a transformer or across the air-gap of an induction motor. The unit of measurement of reactive power is the VAR. Apparent power, which is measured in kilovolt-ampere (kVA), is the total required to operate the equipment, and includes both active and reactive components. *Power factor (PF) is the ratio of active power to apparent power.* Power factor ranges from 0 to 1, with a higher value representing a better PF. In linear, or sinusoidal system, the power factor is based on the phase relationship between reactive and active currents. Power factor can be defined as: $PF = kW/kVA = \cos \Phi$
17	Install Highly Reflective Windows	Windows have a great impact on energy efficiency and comfort levels of a building. Windows can account for 30 to 40% of the heat loss or heat gain in an energy efficient building. In hot, sunny climates, such as in Kuwait, windows have to be selected with spectrally selective tinted glass, or with low-e coating. This type of windows provides low solar heat gain coefficient (SHGC) without loss of light. Darker tinted glass also provides lower SHGC, but it yields somewhat decreased outdoor visibility, particularly at night. Typically windows with low SHGC values are desirable in buildings with higher A/C loads. It is recommended that SHGC has a value less than 0.4. It is also recommended to replace single-pane windows to double-pane windows, and to select new windows with leakage ratings of 0.3 cubic feet per min. or less.
18	Install Cladding/coating the outside walls and roofs	The roof is exposed to the sun for the entire operating day. Light coloured, or cool colour, roofs and highly reflective exterior walls play an important role in reducing cooling loads and saving energy. The energy and cost savings that can be achieved by using cool roofing technologies depend on many factors, such as climate and building characteristics. The coolness of a roof is determined by two main parameters and their combined effect on temperature: Solar reflectance – the fraction of sunlight that is reflected.
19	Install Insulation Walls and Roofs	Adding more wall and roof insulation than normal, during construction, can be done for relatively low-cost premium. Increasing insulation reduces unwanted conductive heat loss (or gain) and consequently improves energy efficiency.
20	Card Access Triggers HVAC and Lighting	Key cards can be used in combination with energy saving devices (ECDs) to trigger air conditioners, lighting and any other equipment. When the employee, or operator, enters the room, he/she insert the card into an energy saving device that can switch on a selection of electrical equipment, mainly A/C and lights. The equipment can be set to switch off immediately, or to remain on for some time after the card has been removed.

Potential Criteria for DSM technology selection

Based on data collection through Phase 1, eleven preliminary criteria were identified. These criteria are subject to screening through Delphi process. The definition of each criterion is shown below.

Table 5.10 the definition of each criterion

#	Criterion name	Description
1	Flexibility for operation and maintenance	Determines that the DSM technology option is easy and flexible in operation and maintenance
2	Durability and reliability	Represented by the duration of DSM technology ownership. Reliability, on the other hand, represents interruptions in usage during that ownership.
3	Capital cost	The capital cost includes initial cost and operational cost during the life of technology.
4	Reduction in consumption	It means the amount of energy (kWh) and demand (kW) reductions that could be achieved with the implementation of DSM alternative.
5	Comfort ability for users	Express the range by which the applied DSM alternative is comfortable to the users.
6	Impact on environment (CO_2, SO_x, NO_x)	DSM has a positive environmental impact. This impact is usually expressed by the amount of emission reductions, mainly reductions in CO_2 or GHG emissions.
7	Payback period	The simple payback period is defined as: PBP = Total capital cost / Net annual savings DSM option with shorter payback period is more cost-effective than with longer payback period.
8	Ease of implementation	This indicates how far the DSM option could be easily implemented. Example is the replacement of traditional incandescent lamps with CFLs having the same fixture
9	Technology life cycle	The course of phases that brings technology into existence and follows its growth into a mature technology and into eventual critical phase and decline. In broad terms the "s" curve suggests four phases of a technology life cycle: emerging, growth, mature and obsolete.
10	Availability of technology	Available and community accepted DSM technology applications are highly recommended. An example of these technologies is the use of CFLs instead of conventional incandescent lamps.
11	After sale services	The services for inspection and maintenance required for the technology by the agent or service company

5.6 The Delphi Method

In order to address the questions of:

1. What Demand Side Management alternatives should be included in the selection process for the optimal demand side management technologies in governmental buildings?
2. What are the criteria that influence the selection process in the Delphi technique? (The Delphi technique is considered a useful tool; it has been deemed a strong methodology for answering questions based on expertise from a panel of selected participants.

5.6.1 Population and sample

The success of a Delphi study is largely dependent on the quality of the participants. The respondents' level of energy management expertise for this study was judged to be high, given the fact that all of the respondents had knowledge and experience in the energy management. They were selected for different sectors to be representative of their sector as a whole to allow for a broader range of expertise and expanded feedback.

5.6.2 The number of participants

It is an important factor to consider the minimum number of participants to ensure a good group performance. Dalkey and Helmer (1963) used a panel of seven experts in their original Delphi study. In this study, the same experts who participated in phase one were invited to participate in the next phase with the goals of:

1. Involving the experts in all research phases
2. Utilizing the same experts knowledge to obtain the appropriate alternatives and criteria by them in first phase

The Delphi techniques do not require a statistical sample, however the panel must be qualified in that they have a deep understanding of the issue under investigation.

In this study, 28 experts were invited again for Delphi phase. Five of them participated in the pilot test; only a total of 20 participated to round one and round two. The results of the expert consensus are based on every group's judgment and are handled independently. Table 5.11 summaries the experts involved in this phase.

Table 5.11Energy experts participate Research Phase Two (DELPHI method)

Group	University / Institute/Company	Department /Section	Sent	Received
Academics	Kuwait University	College of Engineering & Petroleum – Mechanical Engineering Department	3	2
Academics	Kuwait Institute for Scientific Research	Energy & Building Technologies Department	4	3
Academics	Public Authority for Applied Education and Training	Mechanical Engineering and Refrigeration Department	6	5
Owners	Public Authority of Housing	Engineering Design Department	3	2
Owners	Ministry of Religion Affairs	Engineering Affairs Department	4	3
Consultants	Engineering System Groups	Engineering Design Section	3	1
Consultants	PACE Consulting Engineers	Engineering Design Section	3	2
Contractors	Kazema Global Holding	Engineering Services Section	2	2
Total			28	20

5.4.3 Number of rounds

Determining the number of rounds necessary to reach a stable level of consensus is crucial for the success of a Delphi study (Martino, 1993). In general, the number of rounds varies between two and four. This study has completed two rounds in order to obtain consensus from the experts. A sufficient level of consensus has been attained by analysing mean rank and standard deviations of results as explained.

5.4.4 Delphi Questionnaire

The first step in Delphi technique is to design and develop a questionnaire or several questionnaires. In our research study, the main objective of the questionnaire has been to determine the most important DSM alternatives and criteria for their evaluation by using the experts' opinion in this field. The first model of questionnaires comprises the list of pre-selected DSM alternatives and addresses the following question:

"Please determine the importance of demand side management alternatives for existing buildings below"

Experts were asked to rank the alternatives and criteria in order of importance. The questions were recorded on a 9-point Likert scale identifying each alternative and criterion as 'very important' (9), 'Normal' (5), and 'Very unimportant' (1).

The question is repeated for each type of building (three existing and three new). An example of the questionnaire for existing office buildings is given below in Table 5.12

Table 5.12 Round 1; Evaluation of Existing office building DSM alternatives by Academics

	DSM alternatives	**The importance of DSM alternatives**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Very unimportant		Unimportant		Normal		Important		Very important
1	Install Programmable Thermostats	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Install high efficient A/C units	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Variable Frequency Drives	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Retrofit Cooling recovery unit	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Remote control for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Shading for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Use of air curtains at entrances	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Sensors for supply/ return air temp.	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Proper maintenance for A/C	☐	☐	☐	☐	☐	☐	☐	☐	☐
10	Install High Efficiency Lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Install time of use control – lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐
12	Install Occupancy Sensors	☐	☐	☐	☐	☐	☐	☐	☐	☐
13	Install Building Management Syst.	☐	☐	☐	☐	☐	☐	☐	☐	☐
14	Card Access Trigger HVAC & light.	☐	☐	☐	☐	☐	☐	☐	☐	☐
15	Install Power Factor Correction	☐	☐	☐	☐	☐	☐	☐	☐	☐
16	Highly reflective glass for windows	☐	☐	☐	☐	☐	☐	☐	☐	☐
17	Cladding/coating the walls and roofs	☐	☐	☐	☐	☐	☐	☐	☐	☐

The second part of the questionnaire is provided with the pre-selected list of criteria and addresses the following question:

"Please determine the importance of criteria that affect the selection of DSM alternatives for existing/new buildings"

The form of this questionnaire is shown in Table 5.13 below.

Table 5.13 Round 1; Evaluation of criteria for Existing/New office building by Academics

#	Criteria	The importance of Criteria								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Very unimportant		Unimportant		Normal		Important		Very Important
1	Flexibility for operation and maintenance.	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Durability and reliability	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Capital cost	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Reduction in consumption	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Comfort ability for users.	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Impact on reduction in environment (CO_2, SOx, NOx)	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Payback period	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Ease of implementation	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Technology life cycle	☐	☐	☐	☐	☐	☐	☐	☐	☐

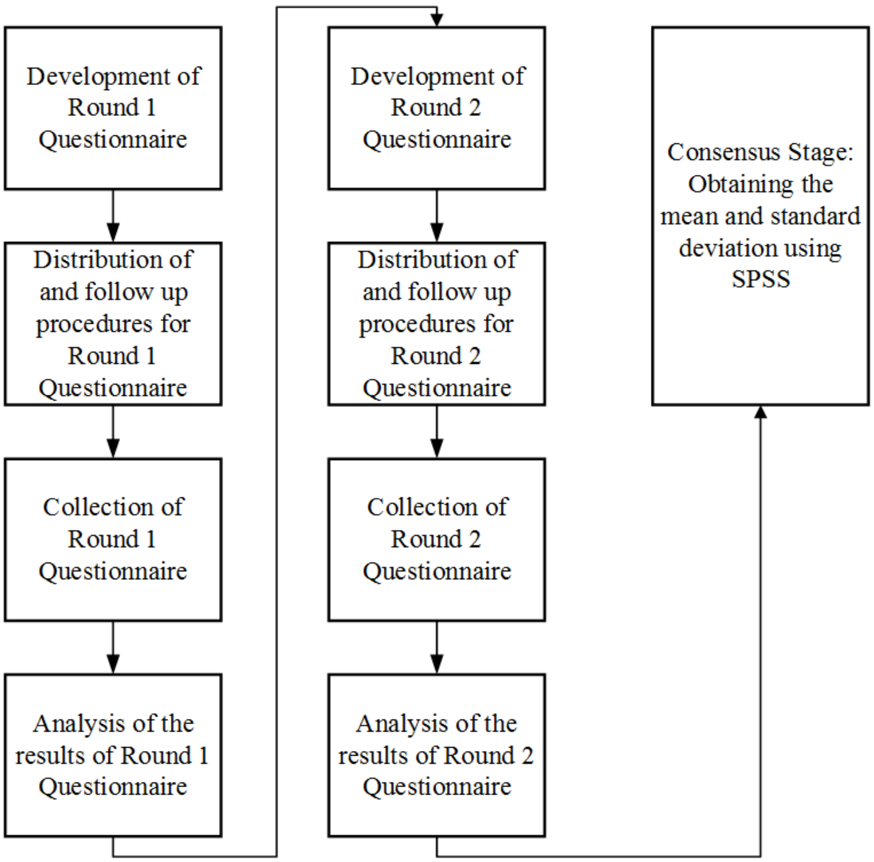


Figure 5.2 Steps of the Delphi procedure

Pilot test for Delphi questionnaire

Before they were sent to the panellists, the questionnaires were pilot tested to ensure the validity and reliability of the questions. Advantages of the pilot test include avoiding the use of complex vocabulary that could be misunderstand by respondents, and making sure that the experts give the same level of concentration to the vocabulary and concepts within the questionnaires. Five energy experts participated in the pilot test; modifications were made by including the recommendations and feedbacks from the experts.

5.7 Results of Delphi Rounds

Delphi techniques usually employ a number of rounds in which questionnaires are sent out and are used until consensus is reached (Benetta, 1996; Green et al., 1999). In each round, a summary of the results of the previous round is included and evaluated by the panel members. The number of rounds depends on how easily consensus is reached on a topic as well as considering the time available and the type of Delphi questionnaire. In general, three rounds are usually recommended; however, due to the time limit and simplicity of the questionnaires used, only two rounds were carried out in this research.

Results from the First Round

The same groups of experts in phase one were invited to participate in the Delphi process; i.e. a total of twenty eight energy experts were invited to participate in the Delphi study and twenty accepted to participate. The Delphi panel members consisted of ten (10) academics, five (5) owners, three (3) consultants and two (2) contractors. Each group of experts was handled independently.

Standard Deviation and mean has been widely used in many studies that involve respondents to rank items (Jeffery et al., 2000). This study also uses standard deviation and means ranking to illustrate movement towards a consensus between rounds. A decreasing of standard deviations between rounds indicated an increase in respondents' agreement level on the importance of issues. The movement towards consensus is shown by an increase in the mean ranking between rounds for the most important items, versus a decrease in the mean ranking for the least important items (Dexter, 1993).

The Statistical Package for Social Science (SPSS) software, version 17, was used to obtain the mean and standard deviation and mean rank of the Delphi questionnaire's questions.

All alternatives for buildings identified by each group based on mean rank are defined. An example of the first round Delphi results for existing office buildings evaluated by academic group is shown in Table 5.14.

Table 5.14 Delphi Statistical Results of Round One for existing Office building evaluated by Academics Group

No.	DSM Option	The Importance of DSM Alternatives											
		Academics Group											
		Exp.1	Exp.2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Avg.	SD
1	Install programmable thermostats	9	*8*	*3*	7	7	8	9	8	8	8	7.5	1.627
2	Install high efficient A/C units	9	*7*	*7*	5	4	8	9	7	8	6	7	1.549
3	Variable frequency drives	9	*8*	*5*	5	5	7	8	7	7	6	6.7	1.345
4	Retrofit cooling recovery unit	7	*6*	*7*	5	4	7	7	6	7	6	6.2	0.979
5	Remote control for A/C units	7	*6*	*3*	7	8	8	7	7	8	8	6.9	1.445
6	Shading for A/C units	3	*8*	*1*	3	2	6	5	2	4	5	3.9	2.022
7	Use of air curtains at entrances	7	*8*	*5*	3	1	5	6	5	4	4	4.8	1.886
8	Sensors for supply & return air temp.	7	*8*	*3*	5	2	5	5	6	5	3	4.9	1.757
9	Proper maintenance for A/C	9	*9*	*5*	5	7	7	6	7	8	7	7	1.341
10	Install high efficiency lighting	9	*8*	*9*	9	7	8	9	8	9	8	8.4	0.663
11	Install time of use control – lighting	9	*8*	*5*	7	7	8	8	7	8	7	7.4	1.019
12	Install occupancy sensors	9	*5*	*7*	7	7	6	6	7	6	7	6.7	1.005
13	Install Building Management Systems (BMS)	9	*9*	*5*	3	5	7	7	7	8	8	6.8	1.833
14	Card access triggers HVAC & lighting	6	*8*	*3*	2	1	5	4	5	3	4	4.1	1.920
15	Install power factor correction	8	*8*	*5*	7	8	7	8	7	6	7	7.1	0.943
16	Highly reflective glass for windows	9	*7*	*7*	7	5	7	8	7	7	6	7	1

17	Cladding/coating outside walls & roofs	9	*8*	*3*	5	3	6	6	5	5	4	5.4	1.854

The results of Round 1 with respect to criteria for both existing and new office building evaluated by the academics group, and the mean value of the scores and standard deviation are calculated and shown in Table 5.15

Table 5.15 Delphi Statistical Results of Round 1 for Criteria

No.	**DSM Option**	**The Importance of DSM Alternatives**											
		Academics Group											
		Ex. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD
1	**Reduction in consumption**	9	9	9	9	9	9	9	9	9	9	9	0
2	**Capital cost**	9	8	5	9	9	9	9	9	9	9	8.5	1.204
3	**Ease of implementation**	9	9	7	8	9	7	8	9	8	9	8.3	0.781
4	**Impact on environment**	9	9	7	7	8	8	7	8	8	8	7.9	0.7
5	**Comfort ability for users**	9	9	9	7	5	7	7	7	8	8	7.6	1.2
6	**Durability and reliability**	9	8	5	7	6	5	8	8	8	8	7.2	1.327
7	**Flexibility for operation and maintenance**	9	8	5	7	5	5	8	7	8	8	7	1.414
8	**Payback period**	9	8	5	5	8	5	7	7	7	8	6.9	1.375
9	**Technology life cycle**	9	8	5	5	7	5	6	7	7	8	6.7	1.345
10	**Availability of technology**	9	9	7	5	5	5	6	7	7	7	6.7	1.418

5.7.1 Results from the Second Round

In the second round, each Delphi participant received a second questionnaire and was asked to review the items summarised by the researcher based on the selections of DSM alternatives and criteria provided in the first round. Every expert was asked to look for feedbacks from other experts and, if he wished, to modify his rate, or “rank-order” items to establish preliminary priorities among items’ scores of the first round. It was clear to all experts in this round that the final selection of DSM alternatives and criteria will be limited to six and five alternatives and criteria respectively. Some experts modified their evaluation as shown in Table 5.16

Table 5.16 Delphi Statistical Results of Round Two for existing Office building evaluated by Academics Group

	DSM Option	The Importance of DSM Alternatives											
		Academics Group											
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Avg.	SD
1	Install High Efficiency Lighting	9	8	9	9	7	8	9	8	9	8	8.4	0.6633
2	Install Programmable Thermostats	9	8	7	7	7	8	9	8	8	8	7.9	0.7
3	Install time of use control – lighting	9	8	7	7	7	8	8	7	8	7	7.6	0.6633
4	Install Building Management Systems (BMS)	9	9	7	7	6	7	7	7	8	8	7.5	0.922
5	Remote control for A/C Units	7	6	8	7	8	8	7	7	8	8	7.4	0.6633
6	Install Power Factor Correction	8	8	7	7	8	7	8	7	6	7	7.3	0.6403
7	Install high efficient A/C units	9	7	7	5	4	8	9	7	8	6	7	1.5492
8	Proper maintenance for A/C	9	9	5	5	7	7	6	7	8	7	7	1.3416
9	Highly reflective glass for windows	9	7	7	7	5	7	8	7	7	6	7	1
10	Variable Frequency Drives	9	8	5	5	5	7	8	7	7	6	6.7	1.3454
11	Install Occupancy Sensors	9	5	7	7	7	6	6	7	6	7	6.7	1.005
12	Retrofit Cooling recovery unit	7	6	7	5	4	7	7	6	7	6	6.2	0.9798
13	Cladding/coating outside walls and roofs	9	8	3	5	3	6	6	5	5	4	5.4	1.8547
14	Sensors for supply & return air temp.	7	8	3	5	2	5	5	6	5	3	4.9	1.7578
15	Use of air curtains at entrances	7	8	5	3	1	5	6	5	4	4	4.8	1.8868

16	Shading for A/C Units	3	8	4	3	2	6	5	2	4	5	4.2	1.7776
17	Card Access Triggers HVAC &Light.	6	8	3	2	1	5	4	5	3	4	4.1	1.9209

Table 5.17 Delphi Statistical Results of Round two for Criteria

Rank	DSM Option	The Importance of DSM Alternatives											
		Academics Group											
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD
1	Reduction in consumption	9	9	9	9	9	9	9	9	9	9	9	0
2	Capital cost	9	8	5	9	9	9	9	9	9	9	8.5	1.20
3	Ease of implementation	9	9	7	8	9	7	8	9	8	9	8.3	0.78
4	Impact on environment	9	9	7	7	8	8	7	8	8	8	7.9	0.7
5	Comfort ability for users	9	9	9	7	5	7	7	7	8	8	7.6	1.2
6	Durability and reliability	9	8	5	7	6	5	8	8	8	8	7.2	1.32
7	Flexibility for Operation and Maintenance	9	8	5	7	5	5	8	7	8	8	7	1.41
8	Payback period	9	8	5	5	8	5	7	7	7	8	6.9	1.37
9	Technology life cycle	9	8	5	5	7	5	6	7	7	8	6.7	1.34
10	Availability of technology	9	9	7	5	5	5	6	7	7	7	6.7	1.41

a) Selection of DSM Alternatives for existing buildings by Academics group

Table 5.18 Delphi Results for Round 1 & 2 for the Academics Group

DSM Alternatives											
For Schools				For Religious buildings				For Offices			
Existing		New		Existing		New		Existing		New	
R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
HEL	HEL	HEL	HEL	HEL	HEL	HEL	HEL	HEL	HEL	HEL	HEL
PGT	PGT	PGT	PGT	PGT	PGT	HEAC	HEAC	PGT	PGT	HEAC	HEAC
TOC	TOC	BMS	BMS	TOC	TOC	TOC	TOC	TOC	TOC	BMS	BMS
VFD	VFD	VFD	VFD	VFD	VFD	VFD	VFD	PF	PF	TES	TES
PF	PF	HEAC	HEAC	HEAC	PF	BMS	BMS	HEAC	BMS	VFD	PGT
POM	RCAC	RCAC	RCAC	RCAC	RCAC	RCAC	RCAC	POM	RCAC	RCAC	RCAC

HEL = High Efficiency Lighting PGT = Programmable Thermostat TOC = Time Of Use Control

RCAC = Remote Control of A/C PF = Power Factor Correction POM = Proper O & M for A /C

TES = Thermal Energy storage for A/C

b) Selection of Criteria

Table 5.19: Delphi Results for Round 1 & 2 for the Academics Group for criteria

Criteria	For Schools	For Religious buildings		For Offices
	Existing & New			
	R1 & R2	R1	R2	R1 & R2
C1	RC	RC	RC	RC
C2	CC	CC	CC	CC
C3	EI	EI	EI	EI
C4	IE	CA	CA	IE
C5	CA	DR	IE	CA

RC = Reduction in Consumption CC = Capital Cost EI = ease of implementation

IE = Environment Impact DR = durability and reliability CA = Comfort ability to users.

5.8 Analysis of Delphi Results

The research study used Delphi process to establish the opinion of the expert groups. Delphi process was carried out in two rounds, and achieved acceptable screening results and consensus for the selection of both DSM alternatives and criteria options.

It is important to emphasize that Based on the results of the Delphi process and discussions with the expert panel, the following main issues were concluded:

- The panel of experts selected six DSM alternatives and five criteria measures as the most important options relative to others. However, few of their choices were modified in the second round.
- The five criteria selected for evaluating DSM technologies are quantitative, such as “capital cost” and “reduction in consumption”; and qualitative, such as “durability and reliability”, “ease of implementation” and “flexible system of operation and maintenance”. It is noticeable that the panel of experts allocated less importance to other criteria, such as “payback period” and “impact on environment”, since they are closely correlated to “capital cost” and “reduction in consumption”, respectively.
- As shown in Table 5.18, almost all selected DSM technology alternatives improve the energy efficiency and peak demand reduction of the two dominating loads, the air conditioning and lighting systems.
- DSM technologies selected for existing buildings differ from those of new buildings. The two DSM technology options included, “Thermal Cool Storage” and Building Management Systems”, which were selected only for new buildings; which is technically logical since these options need special arrangements during building construction.
- From Table 5.18, it is clear that the option of “power factor correction” was selected by experts for existing building. This can be explained as there is no penalty for low power factor in Kuwait (e.g. less than 0.9), which costs the utility much money and increases the total current in the grid; thus large consumers are recommended to improve power factor.

The implications of Delphi results can be summarised as such:

1) Identification of a portfolio of the most critical candidate criteria and DSM technologies for governmental buildings in Kuwait and developing countries which have similar building characteristics and weather conditions.
2) The results indicate that academic energy experts have consensus on high efficient lighting and programmable thermostats and remote control for Air-conditioning technologies as the preferred technologies to be used in all existing and new buildings as a DSM technology option.
3) Building management system (BMS) were recommended by academics for all type of new buildings due to feasibility instead of existing buildings which may need modification in existing technologies to synchronize with retrofit BMS.
4) Emphasis on multiple criteria, including technical, environmental, financial, and social factors

Delphi results support pre-screening criteria list and also contain qualitative and quantitative criteria which emphasise the necessity to be taken in consideration for DSM selection process.

5.9 The AHP Hierarchy Structure

Based on the results of the second round of Delphi process, two compact lists of both DSM technologies and criteria measures were developed. Since some DSM technologies are difficult to be applied in existing buildings, such as cool thermal storage, the experts recommended the use of different lists for existing and new buildings. Table 5.18 and Table 5.19 show a summary of the identified DSM technologies and criteria by the Academics Group for further evaluation by AHP and Fuzzy AHP. Figure 5.3 – Figure 5.8 shows the three-level AHP structure for existing and new buildings as recommended by the Academics Group only.

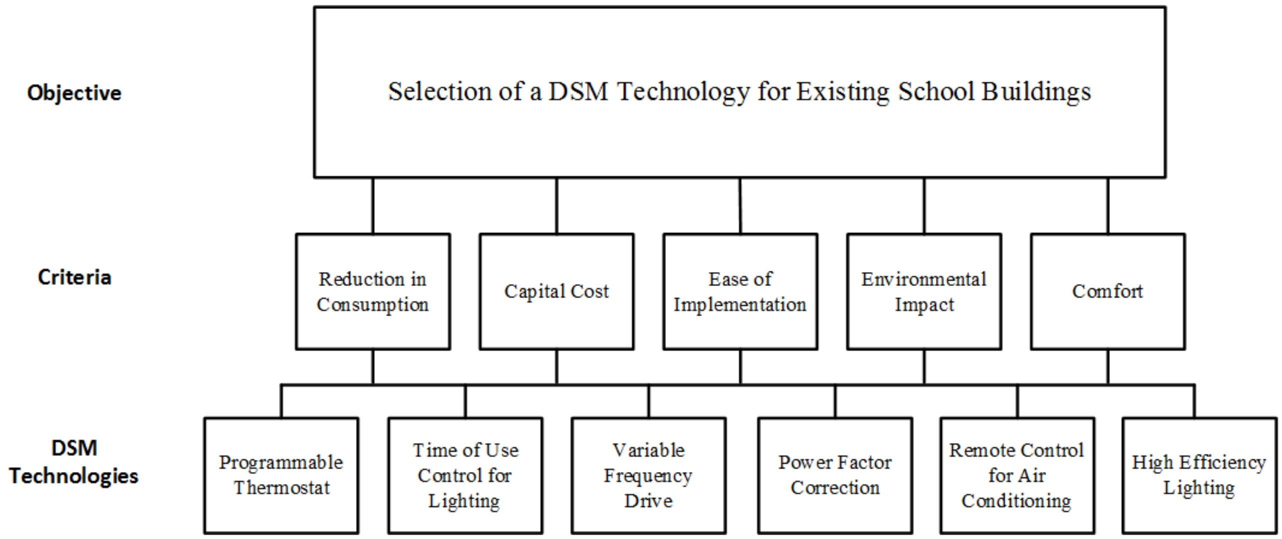


Figure 5.3 The AHP hierarchy for existing school buildings as recommended by academics

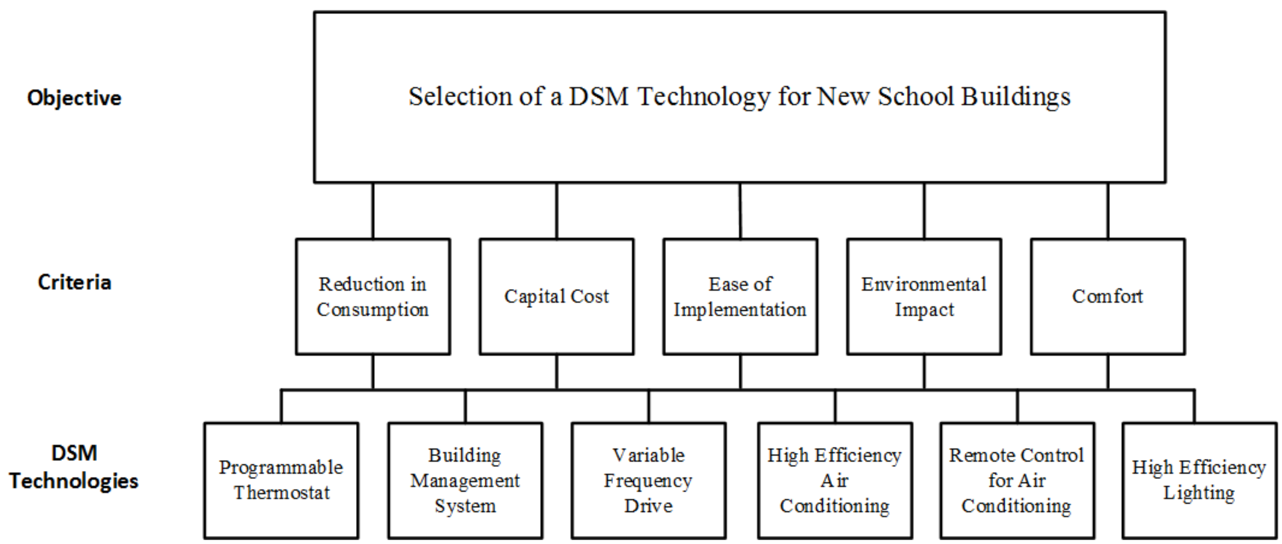


Figure 5.4 The AHP hierarchy for new school buildings as recommended by academics

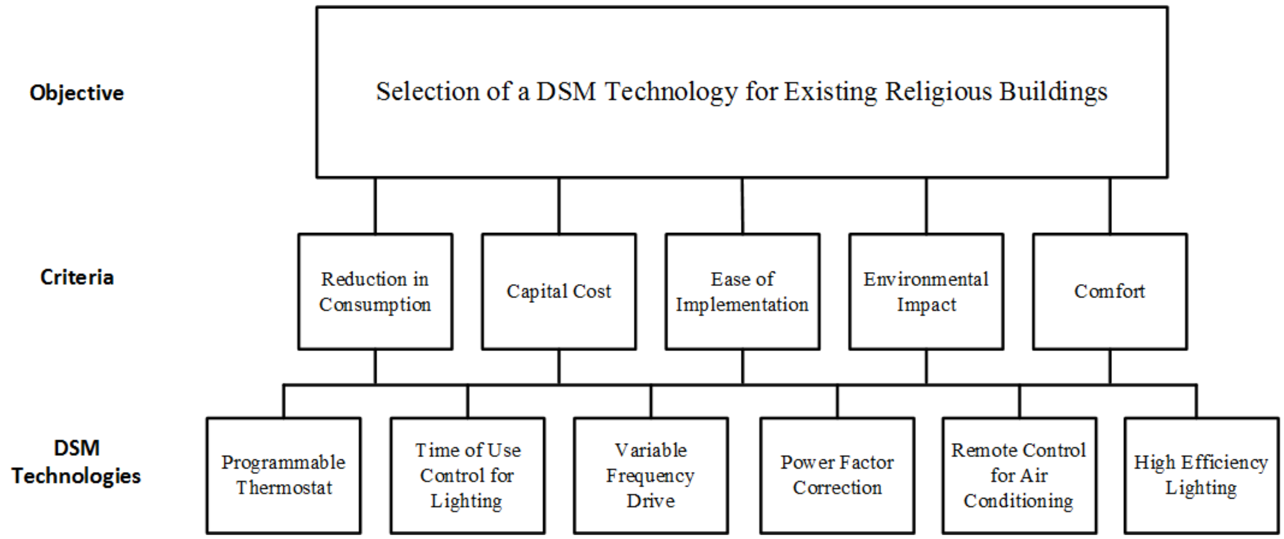


Figure 5.5 The AHP hierarchy for existing religious buildings as recommended by academics

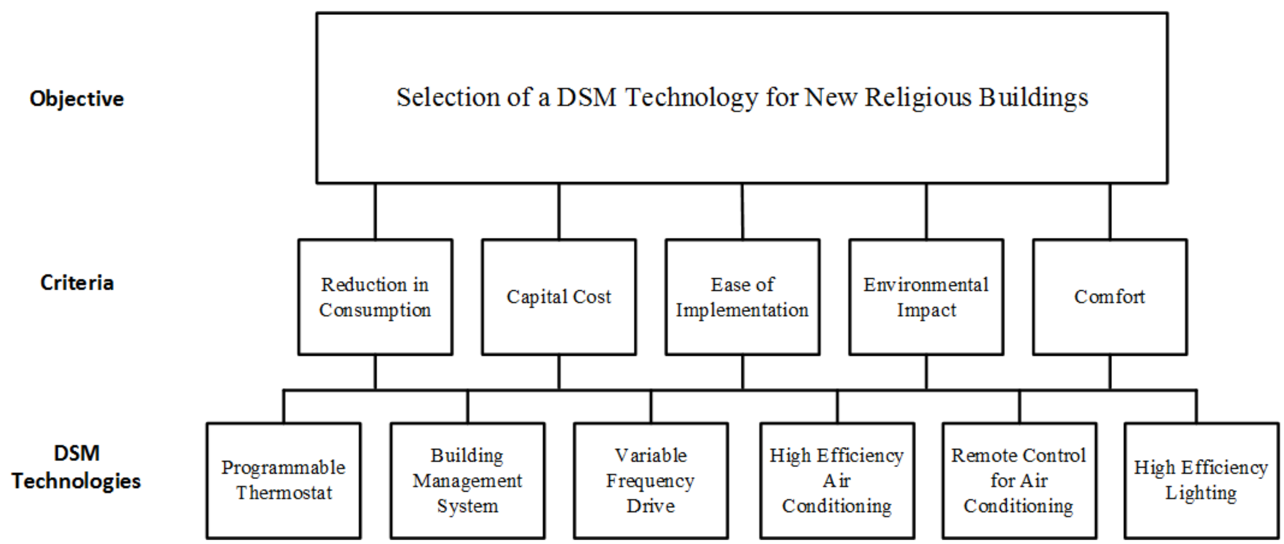


Figure 5.6 The AHP hierarchy for new religious buildings as recommended by academics

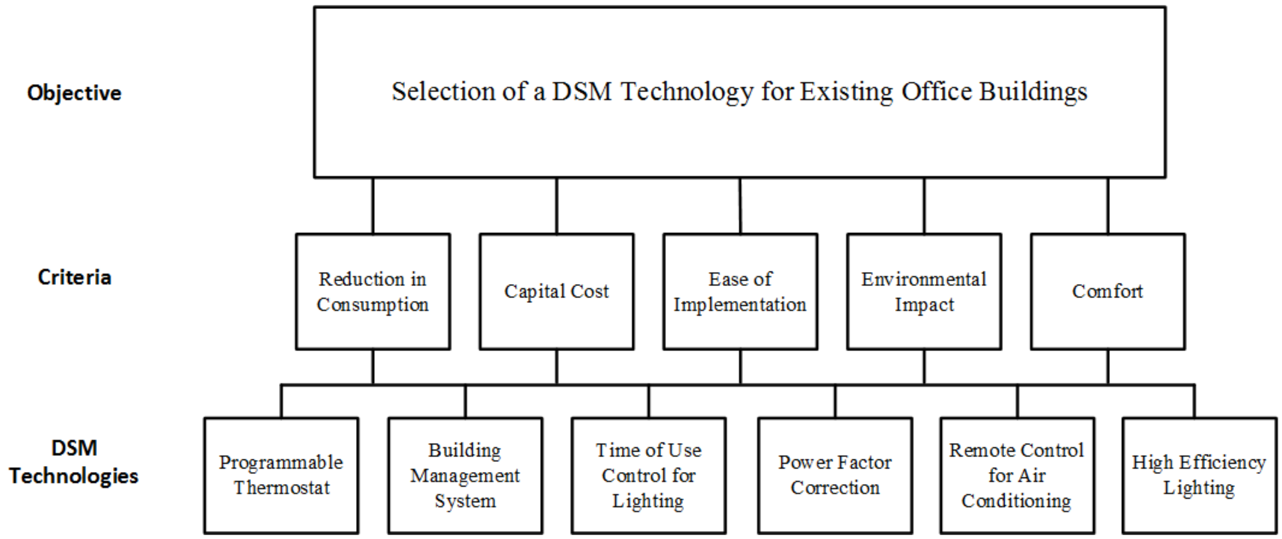


Figure 5.7 The AHP hierarchy for existing office buildings as recommended by academics

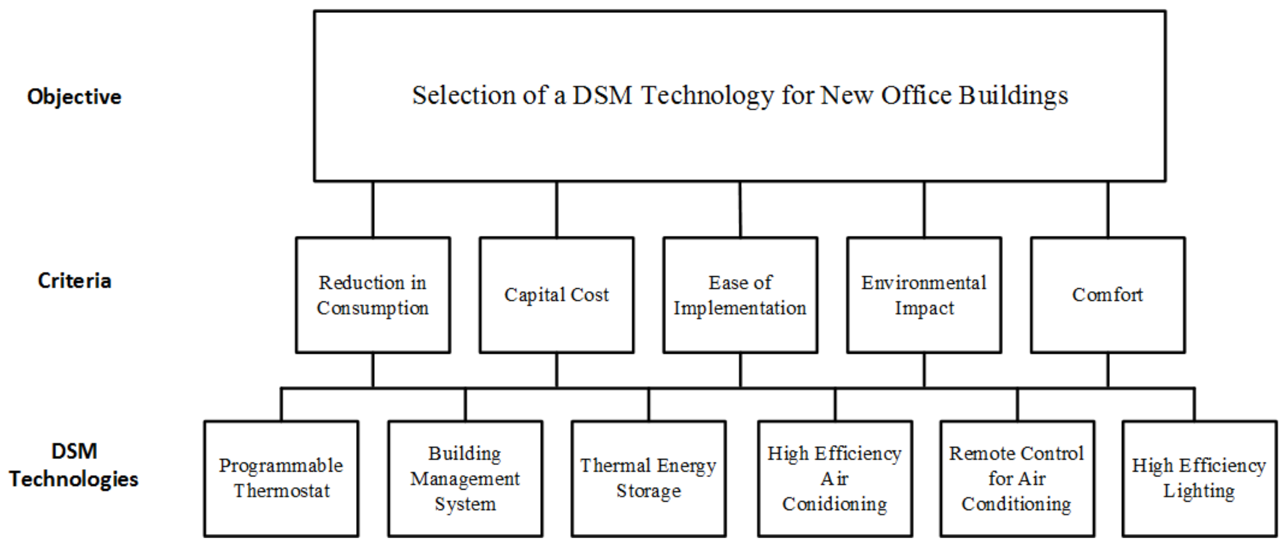


Figure 5.8 The AHP hierarchy for new office buildings as recommended by academics

5.10 Conclusions

Various types of buildings exist in the governmental sector; this study focuses in particular on three types of buildings: schools, religious buildings and office buildings.

An overview of the current energy performance of the selected buildings indicates that there is much potential of energy efficiency improvement, compared with the Code of Practice introduced in Kuwait in 1983.

The raw data of the research including a pre-selected DSM technology options and criteria to be used for their evaluation. The first method involved a literature review, in which the experience of developing countries was reviewed through the local studies and audits conducted in Kuwait, particularly by the Kuwait Institute of Scientific Research. The first method used a semi-structured questionnaire, a portfolio of 21 DSM technology options and 11 criteria for their evaluation were prepared for further investigation by the second research instrument, the Delphi method.

The Delphi technique is an approach used to gain consensus among a panel of experts. The goal of Delphi process, relevant to our research, is to obtain a concrete and sizable list of important DSM technology options and criteria for their judgment. The results from two rounds of this study were organised and compared using descriptive statistics. Delphi panel members from each group advocated six alternatives and five criteria as the important DSM technologies for implementation in each selected building.

Chapter 6. *RESULTS AND DISCUSSION*

6.1 Introduction

In Chapter 5, the Delphi technique was used to gain consensus among a panel of experts from the academic, contractor, consultant, and owner groups. The goal of using the Delphi process, was to obtain a concrete and sizable list of important DSM technology alternatives and a set of criteria for their evaluation. The results from the two rounds of this study were organized and compared using descriptive statistics. The results from the first instrument (data collection) were used to develop the second research instrument (Delphi Questionnaire for each building for all groups shown in Appendix B). These results show that the experts identified six alternative technologies and five criteria for each building for further evaluation in the third phase of the research i.e., Analytic Hierarchy Process (AHP).

In this chapter, analysis is formed in two parts: in Section 6.2, in-depth evaluation and ranking of Delphi output will be performed using the AHP technique, while in Section 6.3 – Section 6.8, in addition to AHP, Fuzzy-AHP technique (FAHP) will be used for ranking the alternatives, and a comparison between AHP and Fuzzy AHP results will be presented.

6.2 Analytical Hierarchy Process

The AHP technique was applied in this research to conduct pairwise comparisons of DSM alternatives. The main advantage provided by AHP is minimizing any bias that could result from subjective judgments (Olson et al., 1986).

An MS Excel sheet implementing the AHP technique was prepared to calculate the weights of each criteria and alternative and the consistency ratio (CR). The application of AHP methodology consists of four steps, which are:

Step 1: Structuring problem and building the AHP model.

Step 2: Collecting data using pairwise comparisons using AHP questionnaire.

Step 3: Normalizing priority weight of the criteria and DSM alternatives.

Step 4: Analysing priority weights of criteria and DSM alternatives.

Based on the identified criteria and DSM alternatives obtained from the Delphi method in Chapter, 5, the criteria and the DSM alternatives for each building type were formulated as a hierarchy as shown in Appendix B. The hierarchies comprise of the overall goal, criteria and DSM alternatives.

In Step 2, the relevant data were collected through questionnaires filled by energy experts on demand management in buildings to determine the relative importance of each criteria and DSM alternative. The nine-point scale as suggested by Saaty (1980) was applied to assign the relative scores. Seventeen demand management experts, who accepted to participate in this research phase, have been selected from different discipline groups and experts in the field of energy management for making pairwise comparison judgments through AHP questionnaire. Each expert was asked to carefully evaluate and assign relative scores using AHP questionnaire with nine-point scale system in a pairwise style with respect to the criteria of one level of hierarchy given the criteria at the next higher level. The process continued in relation to all levels of the entire hierarchy.

As a result, a series of pairwise comparison judgment matrices were obtained with respect to the decision criteria, and the DSM alternatives used in the AHP model. To avoid misunderstanding and confusion, all the correspondents were personally contacted. The questionnaires were clearly explained and each criteria and DSM alternative were clearly defined to them.

The energy experts who participated in this research phase were selected from the same previous groups who participated in the previous research phases to obtain accurate and valid inputs (See Table 6.1). It is to be noted that the respondents were selected from the various groups related to the field of demand management. The selected respondents are:

- Energy experts from academia (8 members)
- Energy experts from consultant firms (2 members)
- Energy experts from contractors (2 members)
- Energy experts from building owners (5 members)

Table 6.1 Energy experts who participated in Phase Three (AHP/FAHP method)

Group	University / Institute/Company	Department /Section	Sent	Received
Academics	Kuwait University	College of Engineering & Petroleum – Mechanical Engineering Department	2	1
Academics	Kuwait Institute for Scientific Research	Energy & Building Technologies Department	3	3
Academics	Public Authority for Applied Education and Training	Mechanical Engineering and Refrigeration Department	5	4
Owners	Public Authority of Housing	Engineering Design Department	2	2
Owners	Ministry of Religious affairs	Engineering affairs Department	3	3
Consultants	Engineering System Groups	Engineering Design Section	1	1
Consultants	PACE Consulting Engineers	Engineering Design Section	2	1
Contractors	Kazema Global Holding	Engineering Services Section	2	2
Total			20	17

It can be noted from Table 6.1 that the number of experts to whom questionnaires were sent out was 20, out which 17 experts responded. This makes the response rate of 85%. The number of experts to whom the questionnaires were sent out in the first phase of the study was 42, out of which 28 experts responded. So the response rate was approximately 67%, which indicates that the experts who were interested in the subject reduced considerably. It is worth mentioning that the experts, who were intended to this phase, participated in all three phases of the questionnaire.

In order to rank the DSM alternatives, the four groups of experts identified six alternatives and five criteria for each building of the study (office, religious, and school). AHP questionnaire, which included pairwise comparisons, were conducted with experts and then these matrices were converted into weights (this is shown in Section 6.3) to priorities the alternatives using the AHP technique. Then, the geometric mean was applied (this is shown in Section 6.3) to the results of the members of each group in order to get the overall priority weights of alternatives for each group of experts. It is worth mentioning that the results of their assessment are available in Appendix C for both AHP and FAHP.

It should be noted that an MS Excel spread sheet was designed and developed by the researcher for the implementation of AHP. Moreover, a Visual Basic based application used by Ibrahim et al (2011), was employed for the implementation of FAHP. Step-by-step details of the implementation of both AHP and FAHP are presented in the next section.

6.3 AHP and FAHP Procedures

In this section, step by step example of calculating the weight for criteria and DSM technologies illustrated using AHP excel spread sheet is provided.

The abbreviations used in this chapter are listed in Table 6.2.

Table 6.2 List of abbreviations used for different criteria and DSM alternatives

Abbreviation	Full Name
Criteria	
F.O&M	Flexibility of operations and maintenance
D&R	Durability and Reliability
Cost	Capital Cost
Implementation	Ease of implementation
Reduction	Reduction in consumption
Comfort	Comfort to users
DSM Technologies	
H.E.L	High Efficiency Lighting
H.E.A.C	High Efficiency Air Conditioning
TOU	Time of Use Control lighting
PGT	Programmable Thermostat
P.F	Power Factor Correction
RC	Remote Control for Air Conditioning
BMS	Building Management System
Maint. A/C	Maintenance of Air Conditioning

TES	Thermal Energy Storage
VFD	Variable Frequency Drive

6.3.1 AHP procedure:

The AHP procedure consists of the following steps:

1. Based on questionnaire survey, comparison matrices were built in a spreadsheet. A screenshot of the spreadsheet is shown below in Figure 6.1 – Figure 6.3. In the spreadsheet, the criteria are listed in rows and columns. The diagonal is filled with the value 1 (See. Figure 6.2), while the cells in the upper half are filled directly from the experts' inputs in AHP questionnaire (See. Figure 6.3). On the other hand, the values in the lower half of the diagonal are obtained using the following formula:

$$a_{ji} = \frac{1}{a_{ij}}$$

Where 'i' and 'j' represent the rows and columns of the matrix and 'a' represents the value in a cell.

	A	B	C	D	E	F
1	**Pairwise comparisons among objective**					
2		Reduction	Cost	D & R	F.O&M	Implement
3	Reduction					
4	Cost					
5	D&R					
6	F.O&M					
7	Implement					
8	Sum					
9						
10						

Figure 6.1 Screenshot of the developed spreadsheet without any value

	A	B	C	D	E	F
1	**Pairwise comparisons among objective**					
2		Reduction	Cost	D & R	F.O&M	Implement
3	Reduction	1				
4	Cost		1			
5	D&R			1		
6	F.O&M				1	
7	Implement					1
8	Sum					
9						
10						

Figure 6.2 Screenshot of the developed spreadsheet with the diagonal filled with value 1.

	A	B	C	D	E	F
1	**Pairwise comparisons among objective**					
2		Reduction	Cost	D & R	F.O&M	Implement
3	Reduction	1		5		
4	Cost		1			
5	D&R	0.2		1		
6	F.O&M				1	
7	Implement					1
8	Sum					
9						

Figure 6.3 Screenshot of the developed spreadsheet with the diagonal filled and sample values for (D&R, Reduction) and (Reduction, D&R) assigned as 0.2 and 5 respectively.

The values of the cells can be interpreted from the AHP questionnaire. An example is shown below in Figure 6.4. In this example, the expert has assigned a value 5 to ‘reduction’ compared with ‘Durability and Reliability (D&R)’ which suggests that the expert strongly prefers ‘reduction’ over ‘Durability and Reliability (D&R)’. Cells in the lower triangle of the matrix are simply the inverse of the corresponding cells in the upper triangle - so in B5 we have 0.2=1/5 from cell D3.

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	← (A) More important									(B) More important →								
Reduction	9 ☐	8 ☐	7 ☐	6 ☐	5 ☒	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	D&R

Figure 6.4 An example of the opinion of an expert about the criteria of ‘reduction’ and ‘Durability and Reliability (D&R) ’.

2. Experts' judgments in AHP questionnaire transferred to AHP matrix in the spread sheet is shown in Figure 6.5.

	A	B	C	D	E	F
1	**Pairwise comparisons among objective**					
2		Reduction	Cost	D & R	F.O&M	Implement
3	Reduction	1	1	5	3	3
4	Cost	1	1	5	3	3
5	D&R	0.2	0.2	1	1	0.3333333
6	F.O&M	0.333333	0.3333333	1	1	1
7	Implement	0.333333	0.3333333	3	1	1
8	Sum	2.866667	2.8666667	15	9	8.3333333
9						

Figure 6.5 The AHP spreadsheet filled using the experts' responses in the AHP questionnaire.

3. The priority vector is obtained from normalized Eigen vector of the matrix, the above matrix need normalization first. This is shown in Figure 6.6 and Figure 6.7 where each cell element is divided by the sum of each column to obtain the normalized value. For example in Figure 6.6, cell F3 contains '3'. After normalization, we obtain '0.36' as shown in Figure 6.7. The normalized value is obtained by dividing the value in cell F3 by the value in cell F8.

	A	B	C	D	E	F
1	**Pairwise comparisons among objective**					
2		Reduction	Cost	D & R	F.O&M	Implement
3	Reduction	1	1	5	3	3
4	Cost	1	1	5	3	3 4 5 6 7 8 9 1/2
5	D&R	0.2	0.2	1	1	
6	F.O&M	0.333333	0.3333333	1	1	
7	Implement	0.333333	0.3333333	3	1	
8	Sum	2.866667	2.8666667	15	9	
9						
10						

Figure 6.6 Normalization of the matrix. Each entry in each column is divided by the sum of that column

	A	B	C	D	E	F	G
1	Pairwise comparisons among objective						
2		Reduction	Cost	D & R	F.O&M	Implement	
3	Reduction	1	1	5	3	3	
4	Cost	1	1	5	3	3	
5	D&R	0.2	0.2	1	1	0.3333333	
6	F.O&M	0.333333	0.3333333	1	1	1	
7	Implement	0.333333	0.3333333	3	1	1	
8	Sum	2.866667	2.8666667	15	9	8.3333333	
9							
10							
11	1-Normalized						Weights
12							
13	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822
14	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822
15	0.069767442	0.069767	0.0666667	0.11111111	0.04		0.07146253
16	0.11627907	0.116279	0.0666667	0.11111111	0.12		0.10606718
17	0.11627907	0.116279	0.2	0.11111111	0.12		0.13273385

Figure 6.7 Matrix after normalization. To get priority vector of all elements, the rows of the normalization matrix are averaged.

4. For testing the consistency of the judgment, Consistency Index (CI) is used which is evaluated as:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Here λ_{max} represents the Eigen value while *'n'* is the matrix size. Figure 6.8 - Figure 6.12 show these calculations.

Table 6.3 Average random consistency (RI) (Saaty, 1995)

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Pairwise comparisons among objective												
2		Reduction	Cost	D & R	F.O&M	Implement							
3	Reduction	1	1	5	3	3							
4	Cost	1	1	5	3	3							
5	D&R	0.2	0.2	1	1	0.3333333		A matrix					
6	F.O&M	0.333333	0.3333333	1	1	1							
7	Implement	0.333333	0.3333333	3	1	1							
8	Sum	2.866667	2.8666667	15	9	8.3333333							
9													
10													
11	1-Normalized						Weights						
12													
13	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822						
14	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822		W matrix				
15	0.069767442	0.069767	0.0666667	0.11111111	0.04		0.07146253						
16	0.11627907	0.116279	0.0666667	0.11111111	0.12		0.10606718						
17	0.11627907	0.116279	0.2	0.11111111	0.12		0.13273385						
18													
19													
20	2- Testing for Consistency			Ratio		(Landa)max		CI		RI		CR	
21	A*w	1.763452		5.11340886		5.0999382		0.0249846		1.12		0.02231	
22		1.763452		5.11340886									
23		0.359722		5.03370938									
24		0.540176		5.09276944									
25		0.683101		5.14639464									
26													

Figure 6.8 Testing the consistency of the judgements. Multiplication of matrix row (A) with Normalized weight Column (W).

SUM =MMULT(B3:F3,$G$13:$G$17)

	A	B	C	D	E	F	G	H	I	J	K	L
1	Pairwise comparisons among objective											
2		Reduction	Cost	D & R	F.O&M	Implement						
3	Reduction	1	1	5	3	3						
4	Cost	1	1	5	3	3						
5	D&R	0.2	0.2	1	1	0.3333333		A matrix				
6	F.O&M	0.333333	0.3333333	1	1	1						
7	Implement	0.333333	0.3333333	3	1	1						
8	Sum	2.866667	2.8666667	15	9	8.3333333						
9												
10												
11	1-Normalized						Weights					
12												
13	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822					
14	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822		W matrix			
15	0.069767442	0.069767	0.0666667	0.11111111	0.04		0.07146253					
16	0.11627907	0.116279	0.0666667	0.11111111	0.12		0.10606718					
17	0.11627907	0.116279	0.2	0.11111111	0.12		0.13273385					
18												
19												
20	2- Testing for Consistency			Ratio		(Landa)max		CI		RI		CR
21	=MMULT(B3:F3,$G$13:$G$17)			5.11340886		5.0999382		0.0249846		1.12		0.02231
22	MMULT(array1, array2)			5.11340886								
23		[illegible]		5.03370938								
24		0.540176		5.09276944								
25		0.683101		5.14639464								
26												

Figure 6.9 Testing the consistency of the judgements. Calculation of the Ratio in order to get λ_{max}

SUM =B21/G13

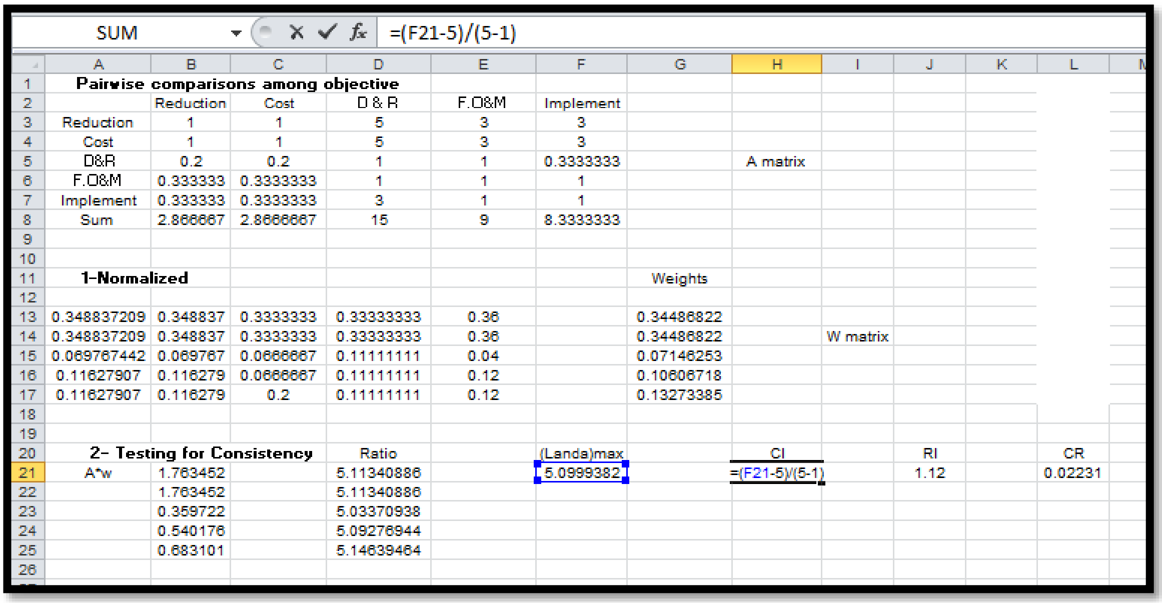
	A	B	C	D	E	F	G	H	I	J	K	L
1	Pairwise comparisons among objective											
2		Reduction	Cost	D & R	F.O&M	Implement						
3	Reduction	1	1	5	3	3						
4	Cost	1	1	5	3	3						
5	D&R	0.2	0.2	1	1	0.3333333		A matrix				
6	F.O&M	0.333333	0.3333333	1	1	1						
7	Implement	0.333333	0.3333333	3	1	1						
8	Sum	2.866667	2.8666667	15	9	8.3333333						
9												
10												
11	1-Normalized						Weights					
12												
13	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822					
14	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822					
15	0.069767442	0.069767	0.0666667	0.11111111	0.04		0.07146253		W matrix			
16	0.11627907	0.116279	0.0666667	0.11111111	0.12		0.10606718					
17	0.11627907	0.116279	0.2	0.11111111	0.12		0.13273385					
18												
19												
20	2- Testing for Consistency			Ratio		(Landa)max		CI		RI		CR
21	A*w	1.763452		=B21/G13		5.0999382		0.0249846		1.12		0.02231
22		1.763452		5.11340886								
23		0.359722		5.03370938								
24		0.540176		5.09276944								
25		0.683101		5.14639464								

Figure 6.10 Testing the consistency of the judgements. Calculation of λ_{max} which is equal to the average$(A.W)/W$.

SUM =AVERAGE(D21:D25)

	A	B	C	D	E	F	G	H	I	J	K	L
1	Pairwise comparisons among objective											
2		Reduction	Cost	D & R	F.O&M	Implement						
3	Reduction	1	1	5	3	3						
4	Cost	1	1	5	3	3						
5	D&R	0.2	0.2	1	1	0.3333333		A matrix				
6	F.O&M	0.333333	0.3333333	1	1	1						
7	Implement	0.333333	0.3333333	3	1	1						
8	Sum	2.866667	2.8666667	15	9	8.3333333						
9												
10												
11	1-Normalized						Weights					
12												
13	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822					
14	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822		W matrix			
15	0.069767442	0.069767	0.0666667	0.11111111	0.04		0.07146253					
16	0.11627907	0.116279	0.0666667	0.11111111	0.12		0.10606718					
17	0.11627907	0.116279	0.2	0.11111111	0.12		0.13273385					
18												
19												
20	2- Testing for Consistency			Ratio		(Landa)max		CI		RI		CR
21	A*w	1.763452		5.11340886		=AVERAGE(D21:D25)		0.0249846		1.12		0.02231
22		1.763452		5.11340886		AVERAGE(number1, [number2], ...)						
23		0.359722		5.03370938								
24		0.540176		5.09276944								
25		0.683101		5.14639464								
26												

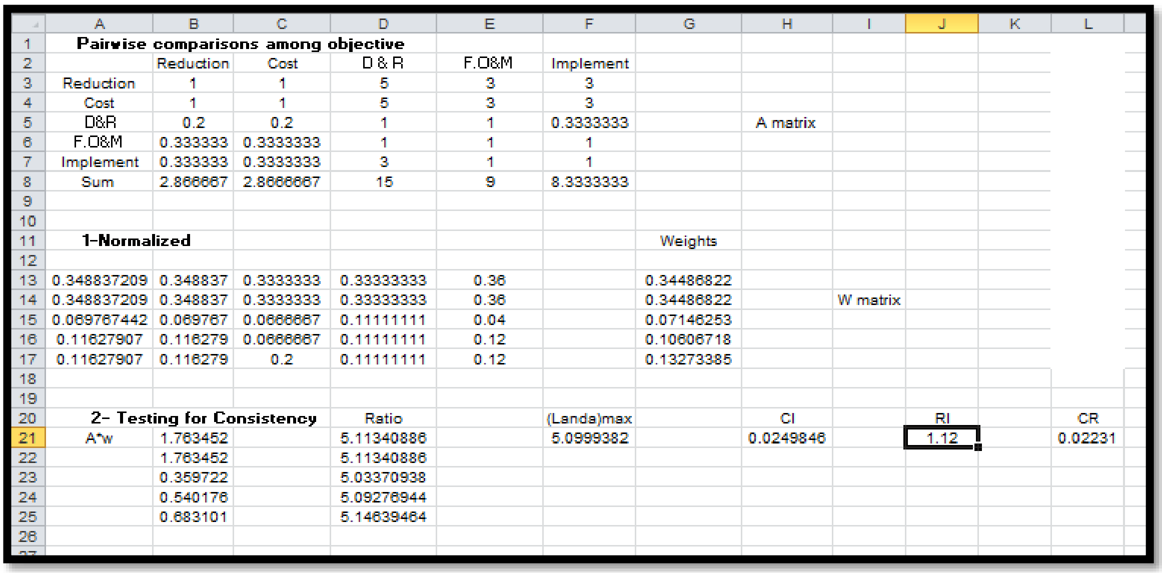
Figure 6.11 Testing the consistency of the judgements. Calculation of Consistency Index



SUM =(F21-5)/(5-1)

	A	B	C	D	E	F	G	H	I	J	K	L
1	Pairwise comparisons among objective											
2		Reduction	Cost	D & R	F.O&M	Implement						
3	Reduction	1	1	5	3	3						
4	Cost	1	1	5	3	3						
5	D&R	0.2	0.2	1	1	0.3333333		A matrix				
6	F.O&M	0.333333	0.3333333	1	1	1						
7	Implement	0.333333	0.3333333	3	1	1						
8	Sum	2.866667	2.8666667	15	9	8.3333333						
9												
10												
11	1-Normalized						Weights					
12												
13	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822					
14	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822		W matrix			
15	0.069767442	0.069767	0.0666667	0.11111111	0.04		0.07146253					
16	0.11627907	0.116279	0.0666667	0.11111111	0.12		0.10606718					
17	0.11627907	0.116279	0.2	0.11111111	0.12		0.13273385					
18												
19												
20	2- Testing for Consistency			Ratio		(Landa)max		CI		RI		CR
21	A*w	1.763452		5.11340886		5.0999382		=(F21-5)/(5-1)		1.12		0.02231
22		1.763452		5.11340886								
23		0.359722		5.03370938								
24		0.540176		5.09276944								
25		0.683101		5.14639464								
26												

Figure 6.12 Testing the consistency of the judgements. Selecting the appropriate Random Consistency Index (RI) as per number of criteria in the matrix



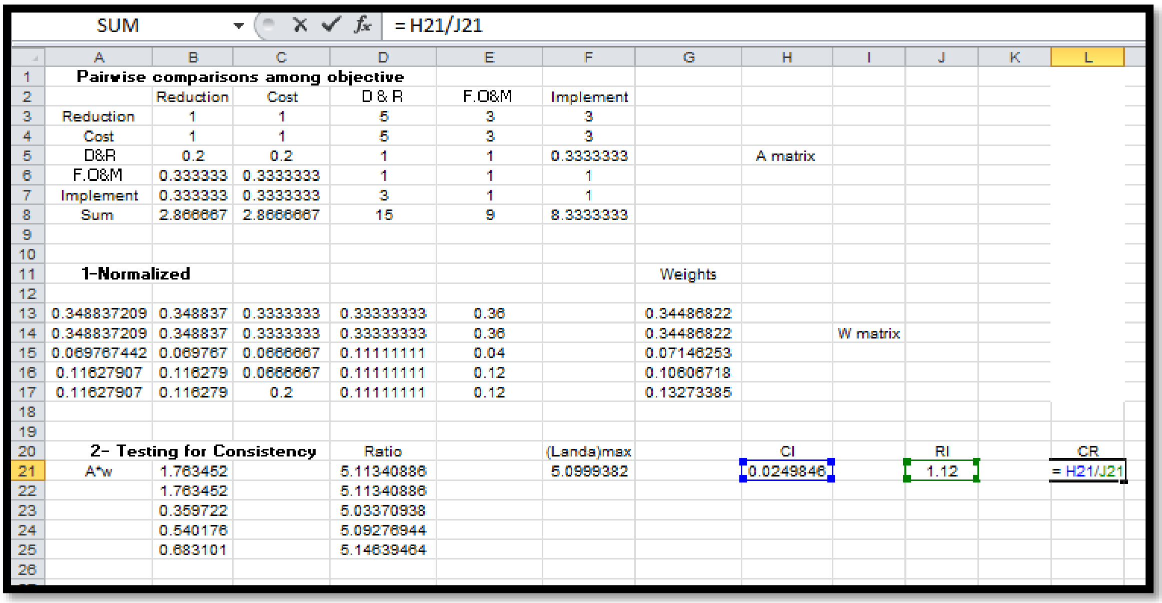
	A	B	C	D	E	F	G	H	I	J	K	L
1	Pairwise comparisons among objective											
2		Reduction	Cost	D & R	F.O&M	Implement						
3	Reduction	1	1	5	3	3						
4	Cost	1	1	5	3	3						
5	D&R	0.2	0.2	1	1	0.3333333		A matrix				
6	F.O&M	0.333333	0.3333333	1	1	1						
7	Implement	0.333333	0.3333333	3	1	1						
8	Sum	2.866667	2.8666667	15	9	8.3333333						
9												
10												
11	1-Normalized						Weights					
12												
13	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822					
14	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822		W matrix			
15	0.069767442	0.069767	0.0666667	0.11111111	0.04		0.07146253					
16	0.11627907	0.116279	0.0666667	0.11111111	0.12		0.10606718					
17	0.11627907	0.116279	0.2	0.11111111	0.12		0.13273385					
18												
19												
20	2- Testing for Consistency			Ratio		(Landa)max		CI		RI		CR
21	A*w	1.763452		5.11340886		5.0999382		0.0249846		1.12		0.02231
22		1.763452		5.11340886								
23		0.359722		5.03370938								
24		0.540176		5.09276944								
25		0.683101		5.14639464								
26												

Figure 6.13 Testing the consistency of the judgements. The Random Consistency Index (RI).

5. Calculate the Consistency Ratio, which is a comparison between Consistency Index and Random Consistency Index. It, can be found by using the following formula:

$$CR = \frac{CI}{RI}$$

Here, Random Consistency Index (RI) is obtained from Table 6.3, where the RI for criteria matrix n = 5, RI = 1.12 (See Figure 6.13) and DSM technologies n = 6, RI = 1.24. A Consistency Ratio of less than 0.1 is deemed acceptable (Saaty, 1980).


SUM = H21/J21

	A	B	C	D	E	F	G	H	I	J	K	L
1	Pairwise comparisons among objective											
2		Reduction	Cost	D & R	F.O&M	Implement						
3	Reduction	1	1	5	3	3						
4	Cost	1	1	5	3	3						
5	D&R	0.2	0.2	1	1	0.3333333		A matrix				
6	F.O&M	0.333333	0.3333333	1	1	1						
7	Implement	0.333333	0.3333333	3	1	1						
8	Sum	2.866667	2.8666667	15	9	8.3333333						
9												
10												
11	1-Normalized						Weights					
12												
13	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822					
14	0.348837209	0.348837	0.3333333	0.33333333	0.36		0.34486822		W matrix			
15	0.069767442	0.069767	0.0666667	0.11111111	0.04		0.07146253					
16	0.11627907	0.116279	0.0666667	0.11111111	0.12		0.10606718					
17	0.11627907	0.116279	0.2	0.11111111	0.12		0.13273385					
18												
19												
20	2- Testing for Consistency			Ratio		(Landa)max		CI		RI		CR
21	A*w	1.763452		5.11340886		5.0999382		0.0249846		1.12		= H21/J21
22		1.763452		5.11340886								
23		0.359722		5.03370938								
24		0.540176		5.09276944								
25		0.683101		5.14639464								
26												

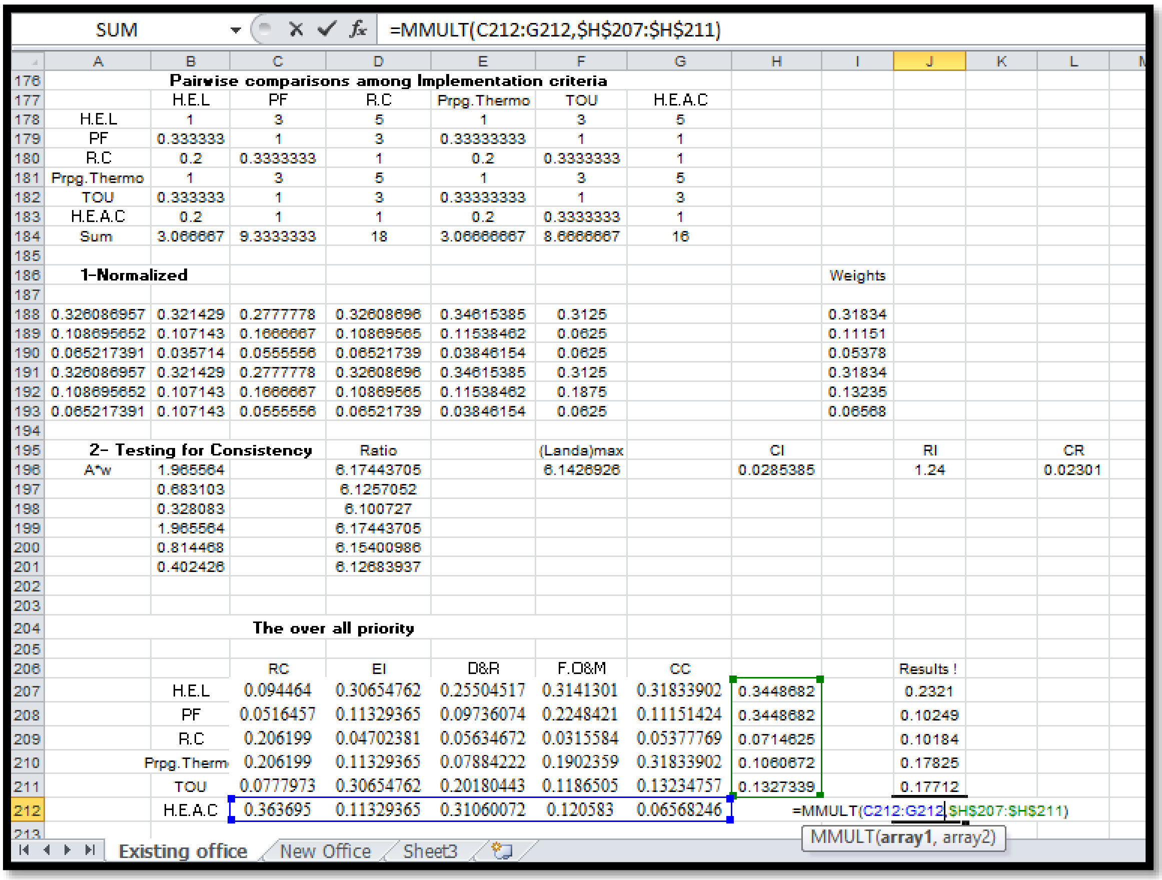
Figure 6.14 Calculating the Consistency Ratio (CR).

6. Step 1 to 5 are repeated for DSM technologies pairwise comparisons with each criteria and when finished we calculate the overall priority by multiplying each row in priority vector for DSM technology (objective) with priority vector of criteria.

	A	B	C	D	E	F	G	H	I	J	K	L
38	**Pairwise comparisons among reduction criteria**											
39		H.E.L	PF	R.C	Prpg.Thermo	TOU	H.E.A.C					
40	H.E.L	1	3	0.33333333	0.33333333	1	0.33333333					
41	PF	0.333333	1	0.2	0.2	1	1/2 1/3					
42	R.C	3	5	1	1	3	1/4					
43	Prpg.Thermo	3	5	1	1	3	1/5					
44	TOU	1	1	0.33333333	0.33333333	1	1/6					
45	H.E.A.C	3	5	3	3	3	1/7					
46	Sum	11.33333	20	5.86666667	5.86666667	12	1/8 1/9					
47												
48	**1-Normalized**								Weights			
49												
50	0.088235294	0.15	0.0568182	0.05681818	0.08333333	0.1315789			0.09446			
51	0.029411765	0.05	0.0340909	0.03409091	0.08333333	0.0789474			0.05165			
52	0.264705882	0.25	0.1704545	0.17045455	0.25	0.1315789			0.2062			
53	0.264705882	0.25	0.1704545	0.17045455	0.25	0.1315789			0.2062			
54	0.088235294	0.05	0.0568182	0.05681818	0.08333333	0.1315789			0.0778			
55	0.264705882	0.25	0.5113636	0.51136364	0.25	0.3947368			0.36369			
56												
57												
58	**2-Testing for Consistency**			Ratio		(Landa)max		CI		RI		CR
59	A*w	0.585896		6.20232233		6.2921444		0.0584289		1.24		0.04712
60		0.31615		6.12150754								
61		1.308642		6.34650136								
62		1.308642		6.34650136								
63		0.482605		6.20335849								
64		2.375901		6.53267554								
65												

Figure 6.15 Calculating the Consistency Ratio for DSM technologies

7. Calculate the overall priority by multiplying each row in priority vector for DSM technology with priority vector of criteria for each expert. This is shown in Figure 6.16



SUM =MMULT(C212:G212,$H$207:$H$211)

	A	B	C	D	E	F	G	H	I	J	K	L
176		Pairwise comparisons among Implementation criteria										
177		H.E.L	PF	R.C	Prpg.Thermo	TOU	H.E.A.C					
178	H.E.L	1	3	5	1	3	5					
179	PF	0.333333	1	3	0.33333333	1	1					
180	R.C	0.2	0.3333333	1	0.2	0.3333333	1					
181	Prpg.Thermo	1	3	5	1	3	5					
182	TOU	0.333333	1	3	0.33333333	1	3					
183	H.E.A.C	0.2	1	1	0.2	0.3333333	1					
184	Sum	3.066667	9.3333333	18	3.06666667	8.6666667	16					
185												
186	1-Normalized								Weights			
187												
188	0.326086957	0.321429	0.2777778	0.32608696	0.34615385	0.3125			0.31834			
189	0.108695652	0.107143	0.1666667	0.10869565	0.11538462	0.0625			0.11151			
190	0.065217391	0.035714	0.0555556	0.06521739	0.03846154	0.0625			0.05378			
191	0.326086957	0.321429	0.2777778	0.32608696	0.34615385	0.3125			0.31834			
192	0.108695652	0.107143	0.1666667	0.10869565	0.11538462	0.1875			0.13235			
193	0.065217391	0.107143	0.0555556	0.06521739	0.03846154	0.0625			0.06568			
194												
195	2- Testing for Consistency			Ratio		(Landa)max		CI		RI		CR
196	A*w	1.965564		6.17443705		6.1426926		0.0285385		1.24		0.02301
197		0.683103		6.1257052								
198		0.328083		6.100727								
199		1.965564		6.17443705								
200		0.814468		6.15400986								
201		0.402426		6.12683937								
202												
203												
204			The over all priority									
205												
206			RC	EI	D&R	F.O&M	CC			Results !		
207		H.E.L	0.094464	0.30654762	0.25504517	0.3141301	0.31833902	0.3448682		0.2321		
208		PF	0.0516457	0.11329365	0.09736074	0.2248421	0.11151424	0.3448682		0.10249		
209		R.C	0.206199	0.04702381	0.05634672	0.0315584	0.05377769	0.0714625		0.10184		
210		Prpg.Therm	0.206199	0.11329365	0.07884222	0.1902359	0.31833902	0.1060672		0.17825		
211		TOU	0.0777973	0.30654762	0.20180443	0.1186505	0.13234757	0.1327339		0.17712		
212		H.E.A.C	0.363695	0.11329365	0.31060072	0.120583	0.06568246		=MMULT(C212:G212,$H$207:$H$211)			

MMULT(**array1**, array2)

Existing office | New Office | Sheet3

Figure 6.16 Calculation of the overall priority.

8. Then calculate the Geometric mean for the group judgments and normalize the resulted Geometric mean for criteria. This is shown in Figure 6.17.

Combination the judjments of all two paritcipants by using the geometric mean

Existing Office Building – Consultants

GM = Geometric mean

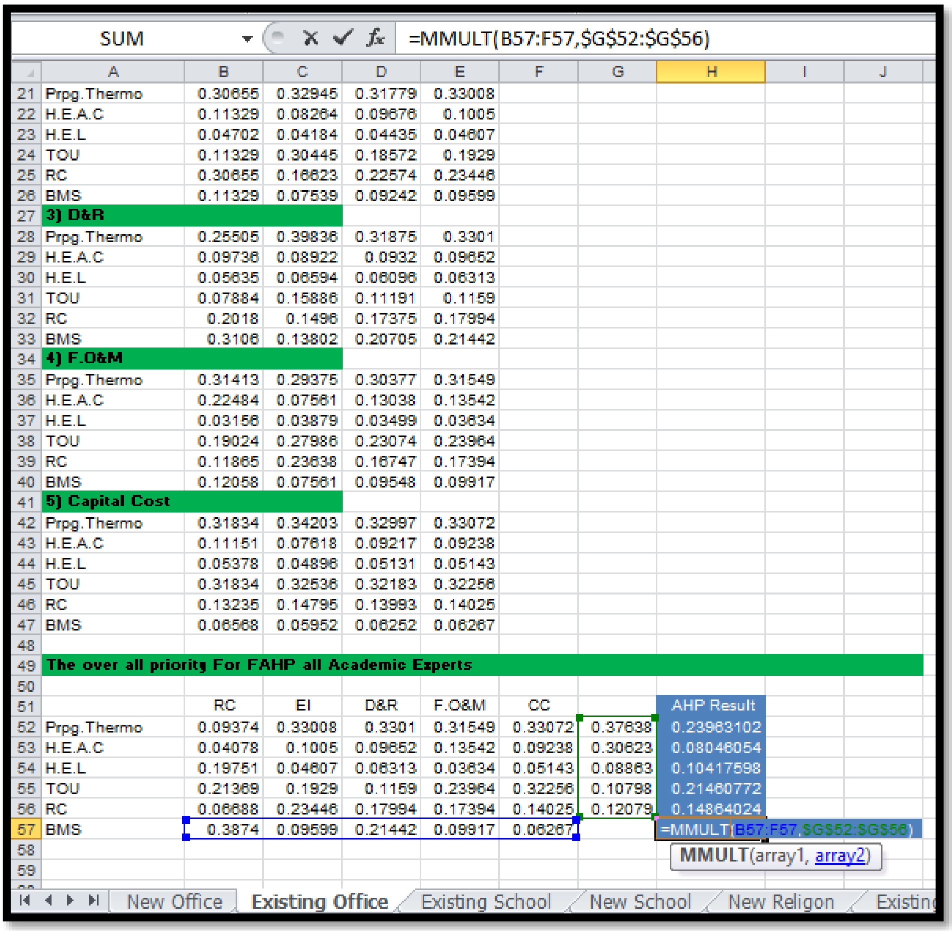
Numbers 1 to 2= the Participants in filling the questionnaire

Among Objectives	1	2	GM	NGM
Reduction	0.34487	0.40571	0.37406	0.37638
Implement	0.34487	0.26857	0.30434	0.30623
D & R	0.07146	0.10857	0.08808	0.08863
F.O&M	0.10607	0.10857	0.10731	0.10798
Cost	0.13273	0.10857	0.12005	0.12079
1) Reduction Criteria				
Prpg.Thermo	0.09446	0.09247	0.09346	0.09374
H.E.A.C	0.05165	0.03201	0.04066	0.04078
H.E.L	0.2062	0.18806	0.19692	0.19751
TOU	0.2062	0.22012	0.21305	0.21369
RC	0.0778	0.05715	0.06668	0.06688
BMS	0.36369	0.41018	0.38624	0.3874
2) Ease Implementation				
Prpg.Thermo	0.30655	0.32945	0.31779	0.33008
H.E.A.C	0.11329	0.08264	0.09676	0.1005
H.E.L	0.04702	0.04184	0.04435	0.04607
TOU	0.11329	0.30445	0.18572	0.1929
RC	0.30655	0.16623	0.22574	0.23446
BMS	0.11329	0.07539	0.09242	0.09599
3) D&R				
Prpg.Thermo	0.25505	0.39836	0.31875	0.3301
H.E.A.C	0.09736	0.08922	0.0932	0.09652
H.E.L	0.05635	0.06594	0.06096	0.06313
TOU	0.07884	0.15886	0.11191	0.1159
RC	0.2018	0.1496	0.17375	0.17994
BMS	0.3106	0.13802	0.20705	0.21442
4) F.O&M				
Prpg.Thermo	0.31413	0.29375	0.30377	0.31549
H.E.A.C	0.22484	0.07561	0.13038	0.13542
H.E.L	0.03156	0.03879	0.03499	0.03634
TOU	0.19024	0.27986	0.23074	0.23964
RC	0.11865	0.23638	0.16747	0.17394

New Office | Existing Office | Existing School | New School

Figure 6.17 Normalization of the geometric mean for criteria

9. Calculate the overall priority (of all experts) (See Figure 6.18) by multiplying each row in priority vector for DSM technology with priority vector of criteria, the highest number indicate the preferred DSM technologies.



SUM =MMULT(B57:F57,$G$52:$G$56)

	A	B	C	D	E	F	G	H
21	Prpg.Thermo	0.30655	0.32945	0.31779	0.33008			
22	H.E.A.C	0.11329	0.08264	0.09676	0.1005			
23	H.E.L	0.04702	0.04184	0.04435	0.04607			
24	TOU	0.11329	0.30445	0.18572	0.1929			
25	RC	0.30655	0.16623	0.22574	0.23446			
26	BMS	0.11329	0.07539	0.09242	0.09599			
27	3) D&R							
28	Prpg.Thermo	0.25505	0.39836	0.31875	0.3301			
29	H.E.A.C	0.09736	0.08922	0.0932	0.09652			
30	H.E.L	0.05635	0.06594	0.06096	0.06313			
31	TOU	0.07884	0.15886	0.11191	0.1159			
32	RC	0.2018	0.1496	0.17375	0.17994			
33	BMS	0.3106	0.13802	0.20705	0.21442			
34	4) F.O&M							
35	Prpg.Thermo	0.31413	0.29375	0.30377	0.31549			
36	H.E.A.C	0.22484	0.07561	0.13038	0.13542			
37	H.E.L	0.03156	0.03879	0.03499	0.03634			
38	TOU	0.19024	0.27986	0.23074	0.23964			
39	RC	0.11865	0.23638	0.16747	0.17394			
40	BMS	0.12058	0.07561	0.09548	0.09917			
41	5) Capital Cost							
42	Prpg.Thermo	0.31834	0.34203	0.32997	0.33072			
43	H.E.A.C	0.11151	0.07618	0.09217	0.09238			
44	H.E.L	0.05378	0.04896	0.05131	0.05143			
45	TOU	0.31834	0.32536	0.32183	0.32256			
46	RC	0.13235	0.14795	0.13993	0.14025			
47	BMS	0.06568	0.05952	0.06252	0.06267			
48								
49	The over all priority For FAHP all Academic Experts							
50								
51		RC	EI	D&R	F.O&M	CC		AHP Result
52	Prpg.Thermo	0.09374	0.33008	0.3301	0.31549	0.33072	0.37638	0.23963102
53	H.E.A.C	0.04078	0.1005	0.09652	0.13542	0.09238	0.30623	0.08046054
54	H.E.L	0.19751	0.04607	0.06313	0.03634	0.05143	0.08863	0.10417598
55	TOU	0.21369	0.1929	0.1159	0.23964	0.32256	0.10798	0.21460772
56	RC	0.06688	0.23446	0.17994	0.17394	0.14025	0.12079	0.14864024
57	BMS	0.3874	0.09599	0.21442	0.09917	0.06267		=MMULT(B57:F57,$G$52:$G$56)

MMULT(array1, array2)

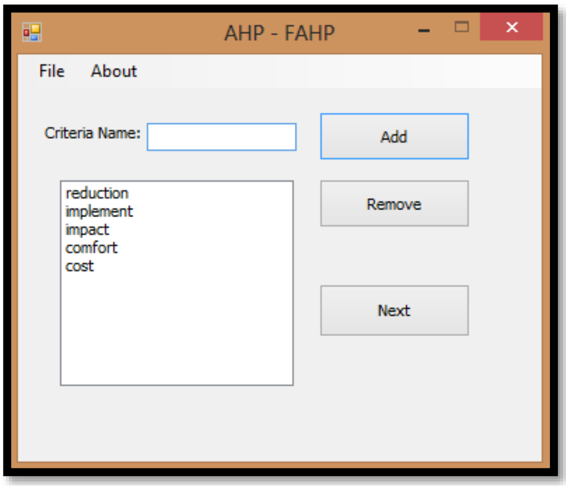
New Office | Existing Office | Existing School | New School | New Religon | Existing

Figure 6.18 Calculation of the overall priority of all experts.

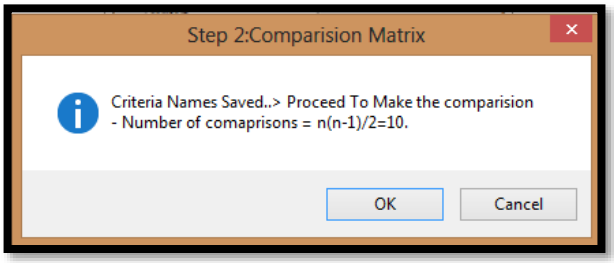
6.3.2 FAHP Procedure

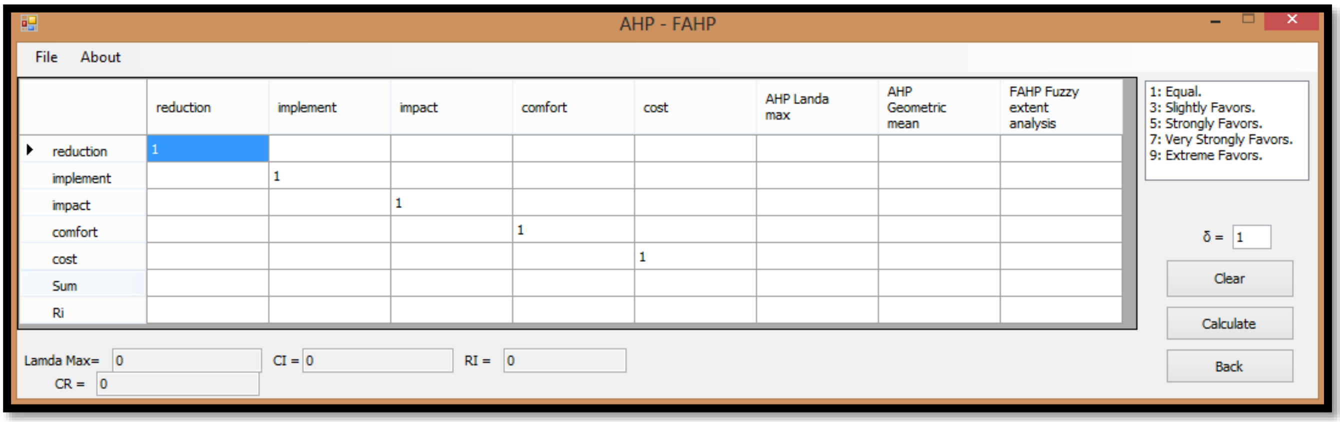
For Fuzzy AHP, a Visual Basic based application used by Ibrahim et al (2011), was employed. The steps involved in the FAHP procedure using this application are given below:

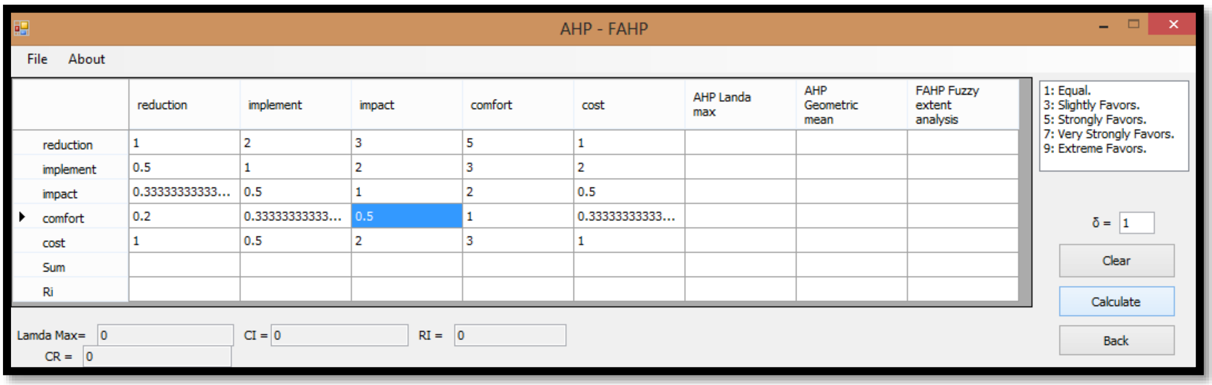
1. Run the program and add the criteria / DSM technologies in the first window.



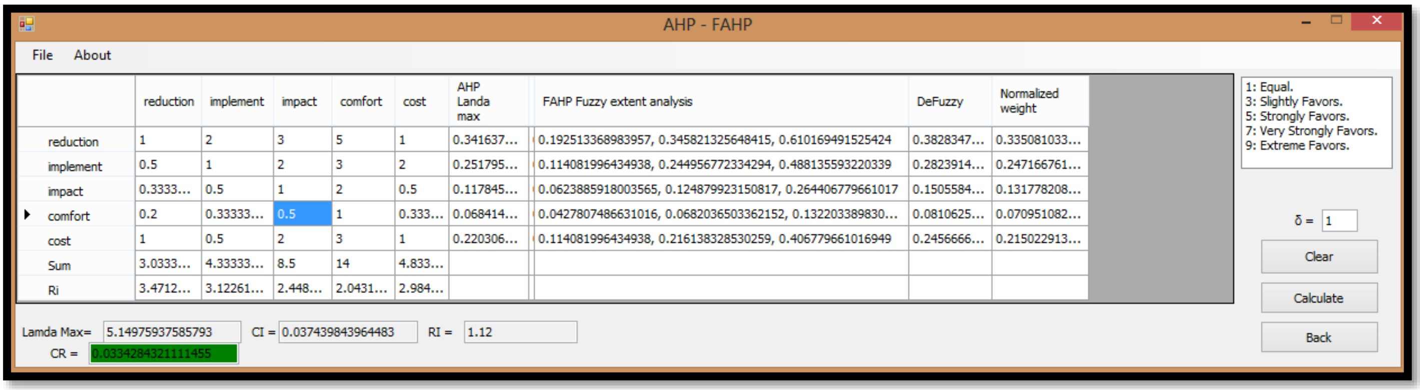
2. Click the "Next" button to move to the second step "Enter the comparison matrix". In the comparison matrix, the score of the cell (x, y) is entered and the program will automatically calculate the reciprocal value in the cell (y, x).







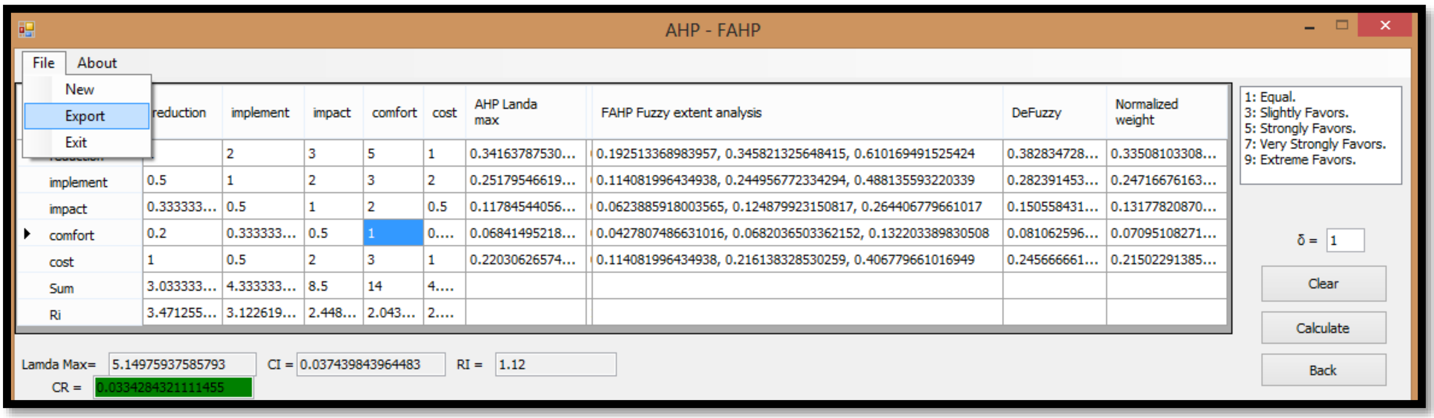
3. Press the ‘calculate’ button to get the weight in AHP and FAHP and consistency

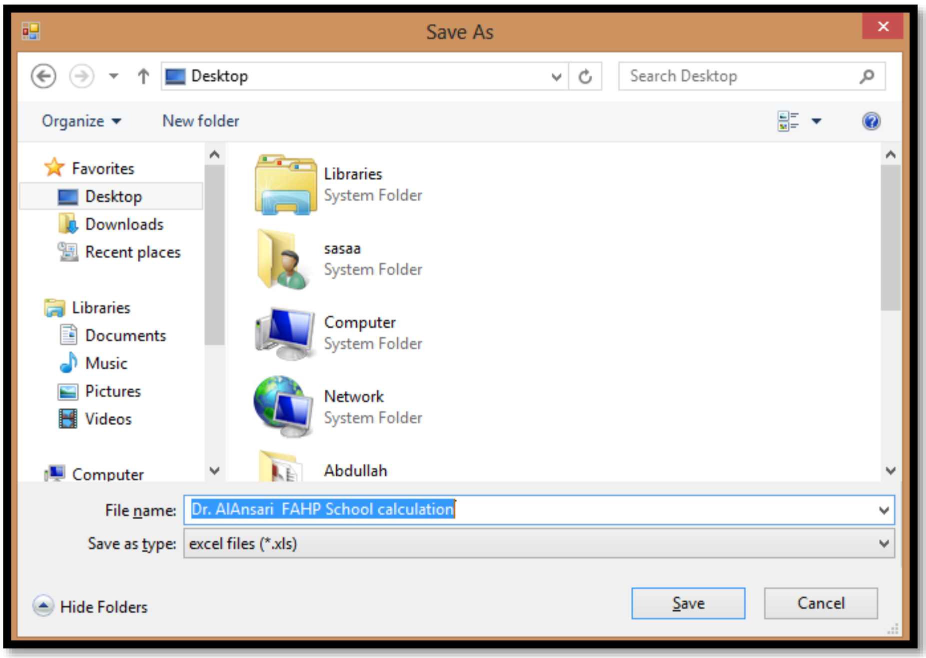


ratio CR in green background if the matrix is consistent and in red if not.

‘

4. The results are exported to an excel sheet for later use.


AHP - FAHP
File
About
New
Export
Exit
1: Equal.
3: Slightly Favors.
5: Strongly Favors.
7: Very Strongly Favors.
9: Extreme Favors.
Clear
Calculate
Back
Lamda Max= 5.14975937585793
CI = 0.037439843964483
RI = 1.12
CR = 0.0334284321111455


Save As
Desktop
Search Desktop
Organize
New folder
Favorites
Desktop
Downloads
Recent places
Libraries
Documents
Music
Pictures
Videos
Computer
Libraries
System Folder
sasaa
System Folder
Computer
System Folder
Network
System Folder
Abdullah
File name: Dr. AlAnsari FAHP School calculation
Save as type: excel files (*.xls)
Hide Folders
Save
Cancel

	A	B	C	D	E	F	G	I	J	K
1	--	reduction	implement	impact	comfort	cost	AHP Landa max	FAHP Fuzzy extent analysis	DeFuzzy	Normalized weight
2	reduction	1	2	3	5	1	0.341637875	0.192513368983957, 0.345821325648415, 0.610169491525424	0.382834729	0.335081033
3	implement	0.5	1	2	3	2	0.251795466	0.114081996434938, 0.244956772334294, 0.488135593220339	0.282391454	0.247166762
4	impact	0.33333333	0.5	1	2	0.5	0.117845441	0.0623885918003565, 0.124879923150817, 0.264406779661017	0.150558432	0.131778209
5	comfort	0.2	0.3333333	0.5	1	0.3333	0.068414952	0.0427807486631016, 0.0682036503362152, 0.132203389830508	0.081062596	0.070951083
6	cost	1	0.5	2	3	1	0.220306266	0.114081996434938, 0.216138328530259, 0.406779661016949	0.245666662	0.215022914
7	Sum	3.03333333	4.3333333	8.5	14	4.8333				
8	Ri	3.47125574	3.122619	2.448	2.04319	2.9849				
9		Landa Max	CI	RI	CR					
10		5.14975938	0.0374398	1.12	0.03343					

5. Step 1 to 4 are repeated with all experts and when the procedure is finished, the geometric mean of the calculate weights is calculated for each criteria and alternative; the result is then normalized to get the final weight for each criteria and alternative.

6.4 Analysis of the results for existing office buildings:

In this section, a graphical comparison between the weights of AHP and FAHP is presented for both the criteria and the DSM alternatives of existing office buildings where the results from all the groups of experts are introduced and discussed. Section 6.4.1 discusses the results of ranking the criteria using both AHP and FAHP and Section 6.4.2 discusses the results of ranking the alternatives using both AHP and FAHP for the existing office buildings.

6.4.1 Comparison of the results obtained for the criteria for existing office buildings

Figures in this section represent AHP and FAHP relative weights results of DSM criteria of existing office buildings for all groups of experts who participated in the questionnaire of this study.

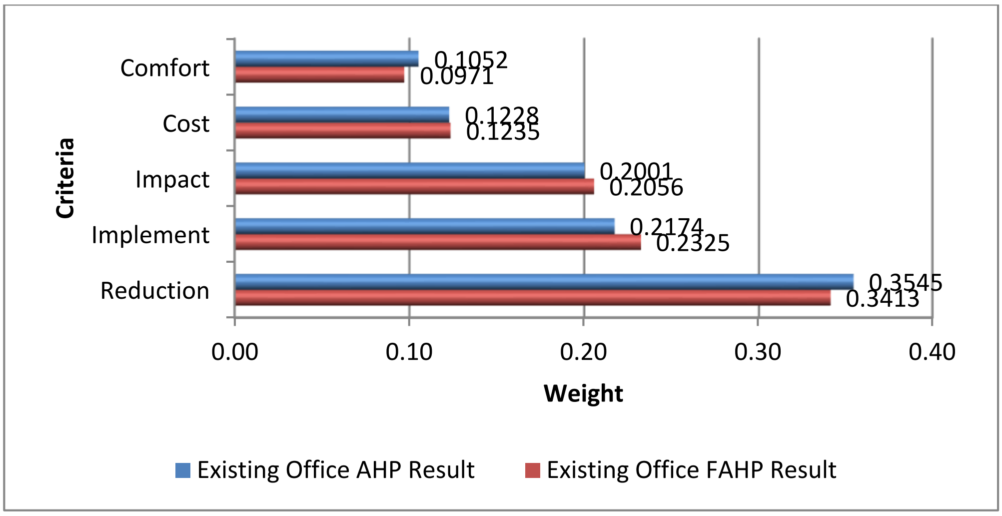


Figure 6.19 Opinion of academics on criteria for existing offices using AHP and FAHP.

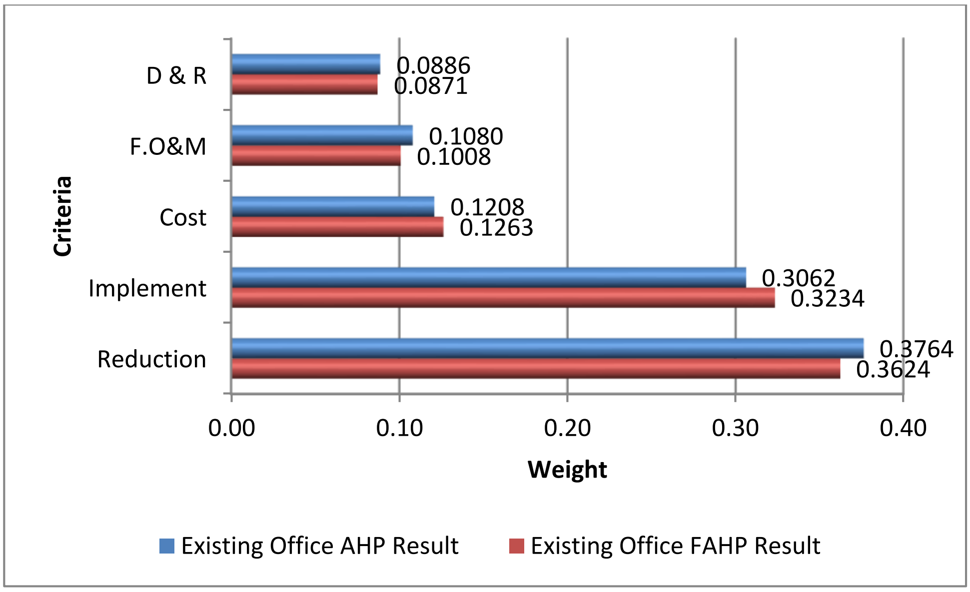


Figure 6.20 Opinion of consultants on criteria of existing offices using AHP and FAHP

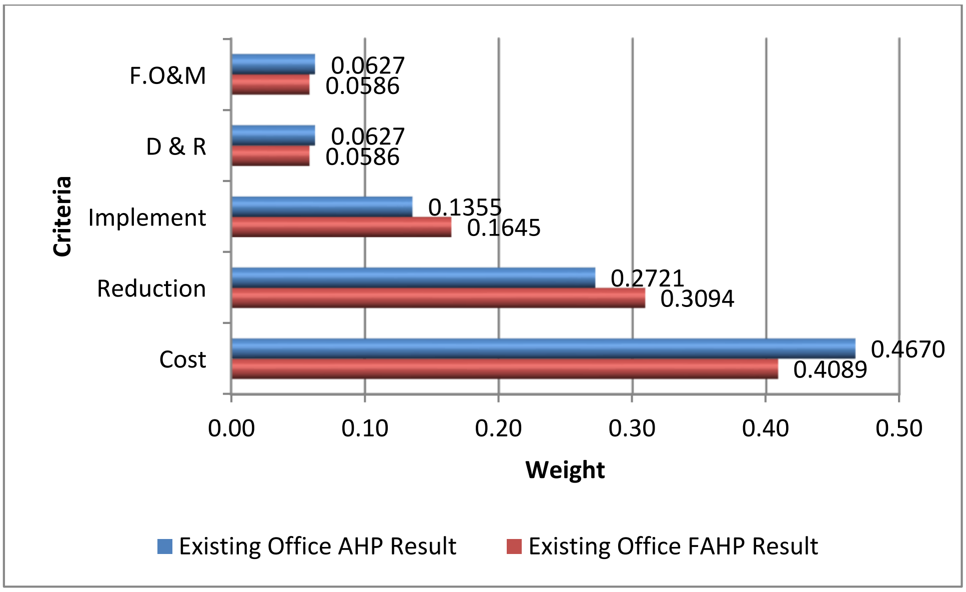


Figure 6.21 Opinion of contractors on criteria of existing offices using AHP and FAHP

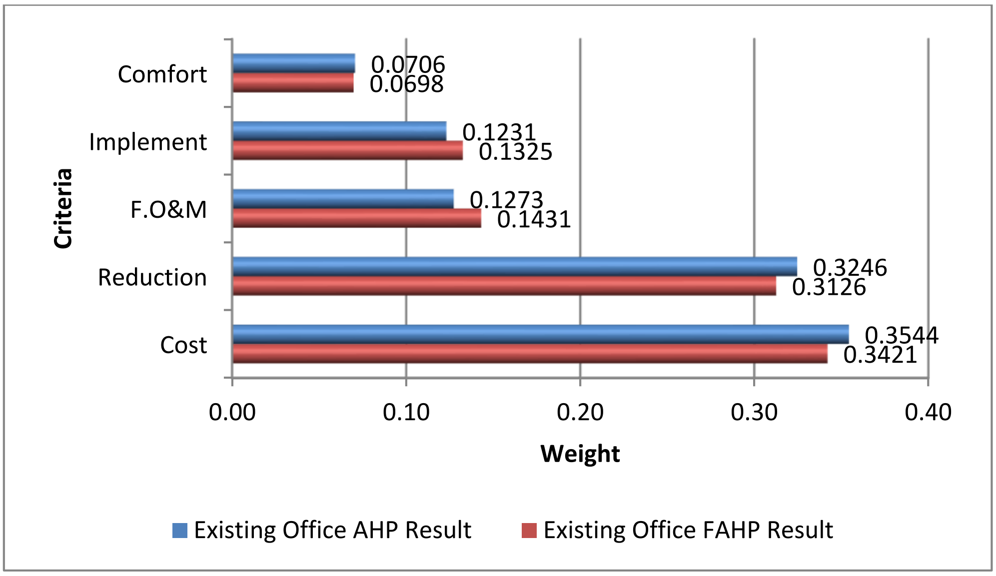


Figure 6.22 Opinion of owners on criteria of existing office using AHP and FAHP.

Figure 6.19 – Figure 6.22 show that results of AHP and FAHP for the main criteria that influence the selection of DSM technology in existing office buildings. The figures show that most of the experts in all the groups agree that reduction in consumption is a recommended criterion for the selection of DSM alternatives in existing office building. Experts from academic and consultancy background gave the highest weights to it,

($W_{AHP=35.44\%}$, $W_{FAHP=34.13\%}$) and ($W_{AHP=37.64\%}$, $W_{FAHP=36.24\%}$) respectively, and ranked it as the most important criteria. Contractors and owners ranked it as the second most important criteria with percentage weights of ($W_{AHP=27.21\%}$, $W_{FAHP=30.94\%}$) and ($W_{AHP=32.46\%}$, $W_{FAHP=31.26\%}$) respectively. A possible motivation behind the selection of reduction of consumption as the most important criteria by the experts could be to reduce the running costs of using electricity. Another possible motivation could be to help to reduce the load on power generation facilities in the country.

Overall, cost seems to be the second most important criterion. It is recommended by contractors and owners as the most important criteria with percentages ($W_{AHP=46.7\%}$, $W_{FAHP=40.89\%}$) and ($W_{AHP=35.44\%}$, $W_{FAHP=34.21\%}$) respectively, while academics rank it in the fourth level with relatively low percentage ($W_{AHP=12.28\%}$, $W_{FAHP=12.35\%}$) and consultants consider it in the third level with similar percentage ($W_{AHP=12.08\%}$, $W_{FAHP=12.63\%}$). The fact that cost was deemed more important by owners and contractors compared to academics and consultants could possibly be attributed to their higher stakes in the cost of the potential new DSM technology from business perspective.

Another important criteria identified by all the experts was the ease of implementation. Academics and consultants consider it in the second level with percentages ($W_{AHP=21.74\%}$, $W_{FAHP=23.25\%}$) and ($W_{AHP=30.62\%}$, $W_{FAHP=23.34\%}$) respectively while contractors consider it in the third level with percentage ($W_{AHP=13.55\%}$, $W_{FAHP=16.45\%}$) and owners consider it in the fourth level among the five proposed criteria with percentage ($W_{AHP=12.31\%}$, $W_{FAHP=13.25\%}$). Understandably, this criterion was deemed less important by the owners as implementation is usually not their domain.

The rest of the criterion are not commonly identified by all the experts. These are flexibility of operation and maintenance and comfort.

Flexibility of operation and maintenance is deemed very important (third out of five) by owners. They assign it weights of ($W_{AHP=12.73\%}$, $W_{FAHP=14.31\%}$). This could be motivated by the fact that, generally, the responsibility of operation and maintenance is borne by the owners. So, it is understandable that they would consider it as an important criterion for selecting a technology. On the other hand, consultants and contractors seem to be relatively less bothered about it and assign it weights ($W_{AHP=10.8\%}$, $W_{FAHP=10.08\%}$) and ($W_{AHP=6.27\%}$, $W_{FAHP=5.86\%}$) respectively. An interesting observation is the lack of interest in this criteria shown by the academics. They do not identify it as an important parameter for selecting an alternative. This could be due to the fact that in case any operation and maintenance work is required, academics are not expected to be involved in such a work.

Comfort was another criterion which was deemed important only by a subset of the four groups i.e., by academics and owners. They assign it weights of ($W_{AHP=10.52\%}$, $W_{FAHP=9.71\%}$) and ($W_{AHP=7.06\%}$, $W_{FAHP=6.98\%}$) respectively. A possible reason for the assignment of a higher rank to comfort by academics and owners could be that academics and owners are expected to be directly related to office buildings and are expected to use them more compared to contractors or consultants.

Finally, durability was identified as an important criterion only by consultants and contractors. They assigned it weights of ($W_{AHP=8.86\%}$, $W_{FAHP=8.71\%}$) and ($W_{AHP=6.27\%}$, $W_{FAHP=5.86\%}$) respectively. A possible motivation for this could be that the contractors are generally wary of their reputation and a compromise on durability and reliability of the potential DSM technology could jeopardize their reputation.

It is important to note that the results obtained using AHP and FAHP are generally consistent i.e. the overall rankings of all the criteria remained consistent for both AHP and FAHP.

6.4.2 Analysis of the results obtained for DSM alternatives for existing office buildings

Figure 6.23 – Figure 6.26 represent the relative weights of AHP and FAHP of DSM alternatives for existing office buildings assigned by the four groups of experts.

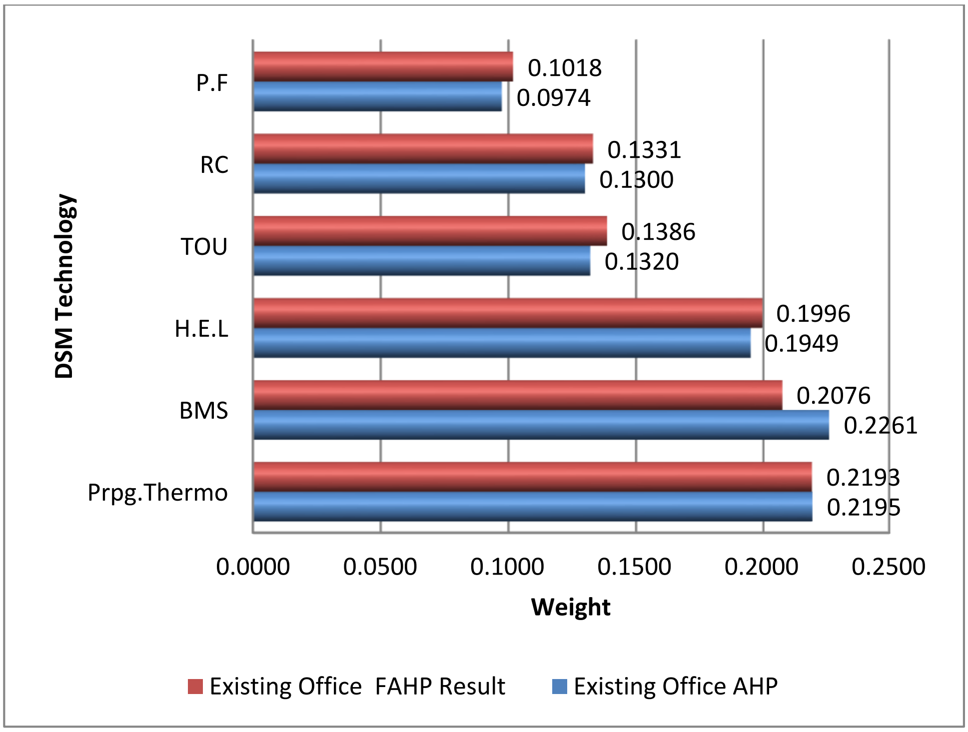


Figure 6.23 Opinion of academics on the DSM alternatives of existing office using AHP and FAHP.

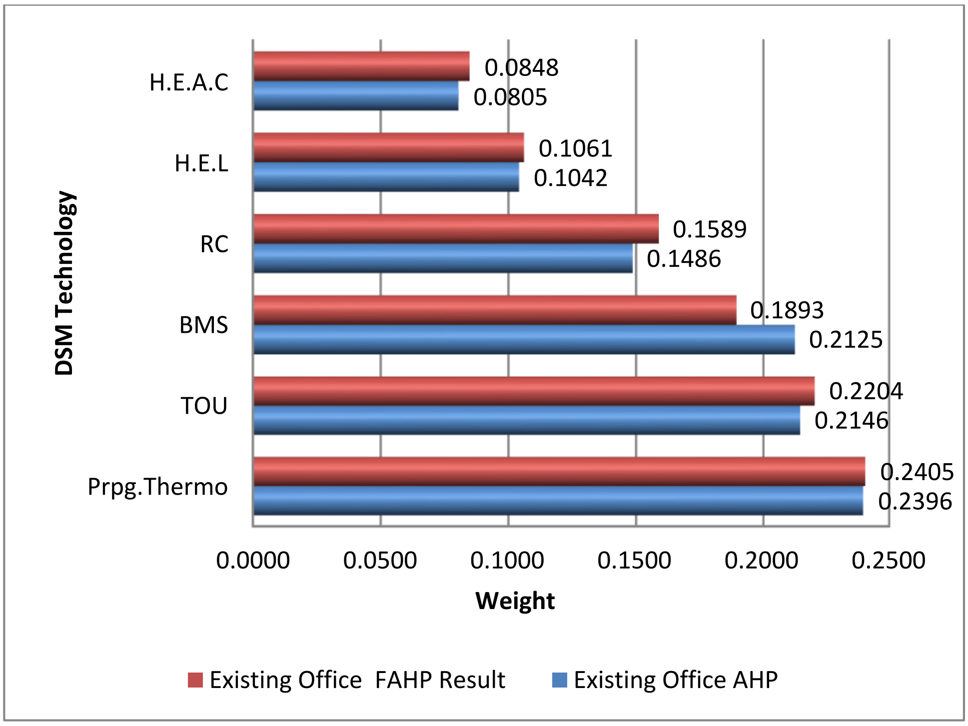


Figure 6.24 Opinion of consultants on the DSM alternatives of existing office using AHP and FAHP.

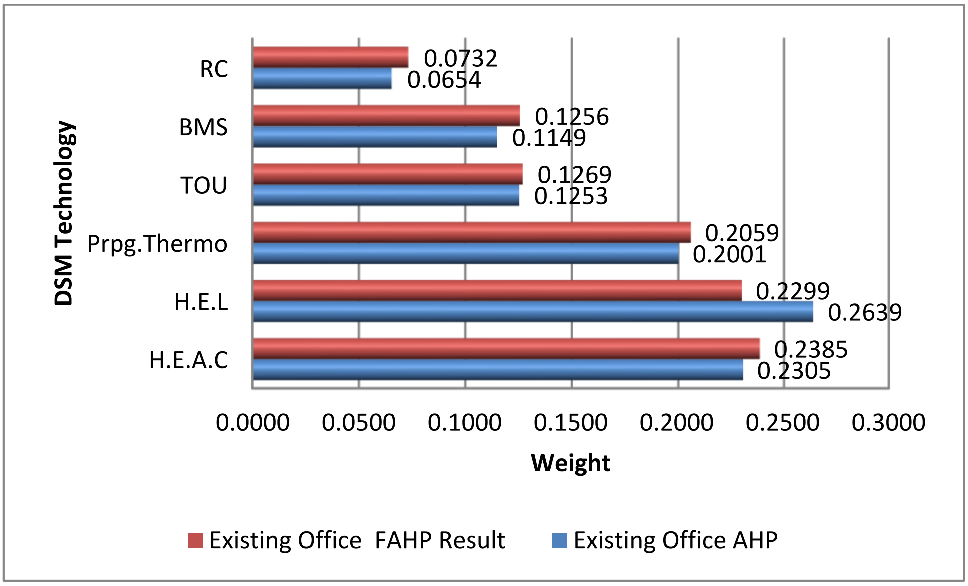


Figure 6.25 Opinion of contractors on the DSM alternatives of existing office using AHP and FAHP.

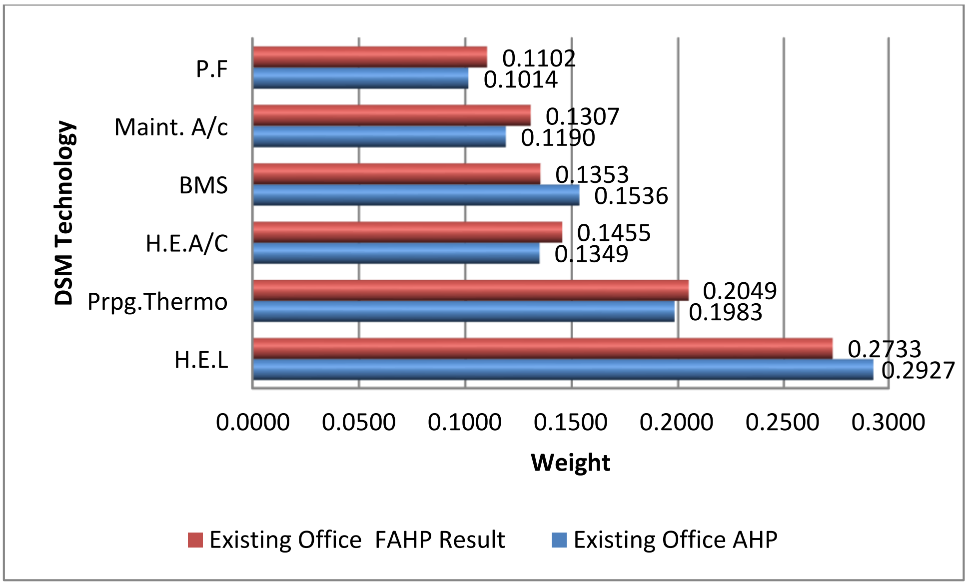


Figure 6.26 Opinion of owners on the DSM alternatives of existing office using AHP and FAHP

In Figure 6.23, while the ranks of the remaining options remain the same for results obtained using both the AHP and the FAHP methods, the top two options selected by academics are different for both AHP and FAHP. For example, according to AHP, building management system (BMS) is the best option followed by programmable thermostat. However, the positions of these options are swapped when results are obtained using FAHP.

Figure 6.24 shows the results obtained using AHP and FAHP for the consultants group. Here, the results obtained using AHP and FAHP are relatively consistent in that they both assign similar ranks to each option, though the individual weights assigned by each of these methods slightly differ. The option that is selected as best using both the method is the programmable thermostat.

Figure 6.25 shows the results obtained using AHP and FAHP for the contractors group. As in the case of Figure 6.23, the results for the first two positions are inconsistent in AHP and FAHP. While according to AHP, high efficiency lighting (H.E.L) is more important than high efficiency air conditioning (H.E.A.C), the results for FAHP are on the contrary. The results for the remaining positions are consistent with slight variations in the assigned weights.

Figure 6.26 shows the results for the owners group. Here, the results for position 3 and 4 are inconsistent for AHP and FAHP, while the results for other positions are consistent. Both the methods indicate that building management system is the most suitable option followed by high efficiency air conditioning.

It is important to note that, considering Figure 6.23 – Figure 6.26, most of the experts in all groups agree that programmable thermostat for air conditioning system is the best option for existing office buildings. This option is given the highest weights by consultants and academics. These are ($W_{AHP=23.96\%}$, $W_{FAHP=24.05\%}$) and ($W_{AHP=21.95\%}$, $W_{FAHP=21.93\%}$) respectively and represent top positions for these groups. Owners rank it as the second option with a percentage weight of ($W_{AHP=19.83\%}$, $W_{FAHP=20.49\%}$) while contractors rank it as the third option with relatively high percentage ($W_{AHP=20.01\%}$, $W_{FAHP=20.59\%}$).

Moreover, it is important to note that the academic experts have not included the option of retrofit high efficiency air conditioning in existing buildings. This option is given completely opposite priorities by consultants and contractors i.e., while the consultants give this option the lowest percentage weight ($W_{AHP=8.05\%}$, $W_{FAHP=8.48\%}$), the contractors consider it as second best option with high percentage ($W_{AHP=23.05\%}$, $W_{FAHP=23.85\%}$). On the other hand owners recommend it as the third best option with a percentage ($W_{AHP=13.49\%}$, $W_{FAHP=14.55\%}$).

Retrofit of building management system in existing office buildings was recommended by academics as the most appropriate DSM option with high percentage ($W_{AHP=22.61\%}$, $W_{FAHP=20.76\%}$). This option is relatively disregarded by other groups, for example consultants consider it as the third best option with a percentage of ($W_{AHP=21.25\%}$, $W_{FAHP=18.93\%}$). It follows time of use rate for lighting which has a weight of ($W_{AHP=22.04\%}$, $W_{FAHP=21.46\%}$). Owners consider it as the fourth best option with a percentage ($W_{AHP=15.36\%}$, $W_{FAHP=13.53\%}$) while contractors consider it in the last place with a percentage ($W_{AHP=11.49\%}$, $W_{FAHP=12.56\%}$).

Correction of power factor (PF) seems to be favoured by owners and academics, while maintenance of air conditioning is chosen only by owner perhaps because owners are generally expected to be more concerned about the costs and hence, are expected to consider maintaining/enhancing existing infrastructure rather than spending money on new solutions. Moreover, the use of remote control (RC) is favoured by all the groups except the owners.

The analysis of the pair-wise judgments of the four groups regarding the selection of the optimal DSM in existing office buildings is considerably robust, as it was found to have an inconsistency ratio of less than 0.1.

It is also to be noted that while the results of AHP and FAHP were largely consistent, there were some notable exceptions. For example, according to AHP, academics seem to prefer building management system over programmable thermostat, while according to FAHP, they choose otherwise. Similarly, according to AHP, contractors seem to favour high efficiency lighting over high efficiency air conditioning, while FAHP suggests otherwise. Moreover, according to AHP, owners seem to favour building management system over high efficiency air conditioning while FAHP suggests otherwise.

6.5 Analysis of the results for new office buildings

In this section, a graphical comparison is made between the weights of AHP and FAHP. The comparisons are made for both the criteria and the DSM alternative selection for new office buildings. The results obtained from all groups of experts will be introduced and discussed.

6.5.1 Comparison of the results obtained for the criteria for new office buildings

Figure 6.27 – Figure 6.30 show the relative weights assigned to each DSM criteria using AHP and FAHP methods for new office buildings by all the groups of experts who participated in the questionnaire of this study.

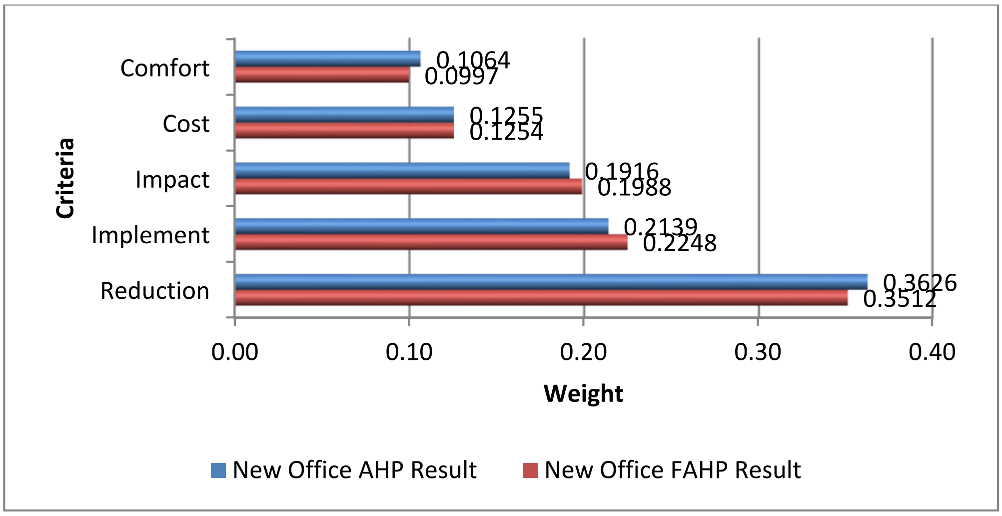


Figure 6.27 Opinion of academics on criteria of new office using AHP and FAHP

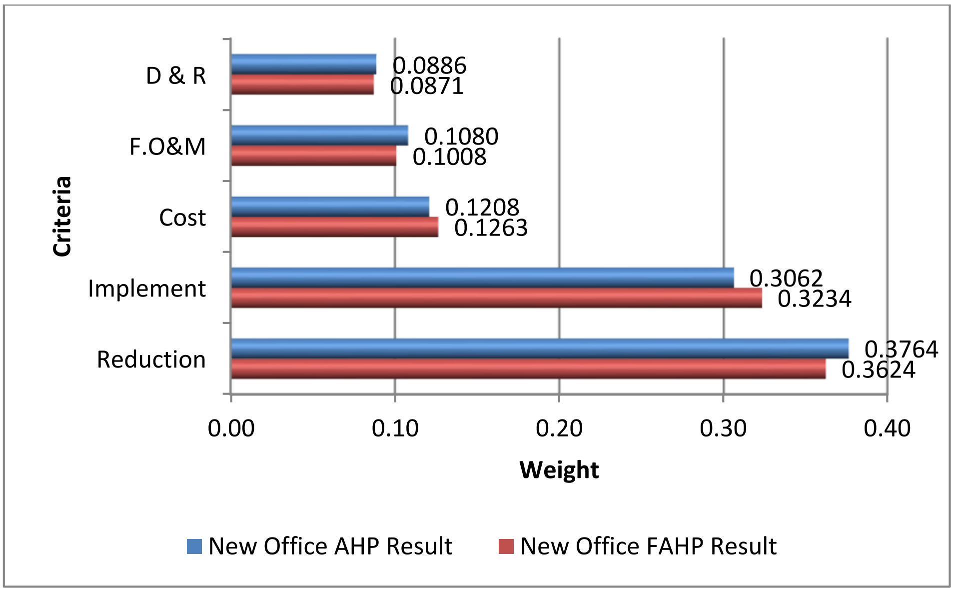


Figure 6.28 Opinion of consultants on criteria of new office using AHP and FAHP

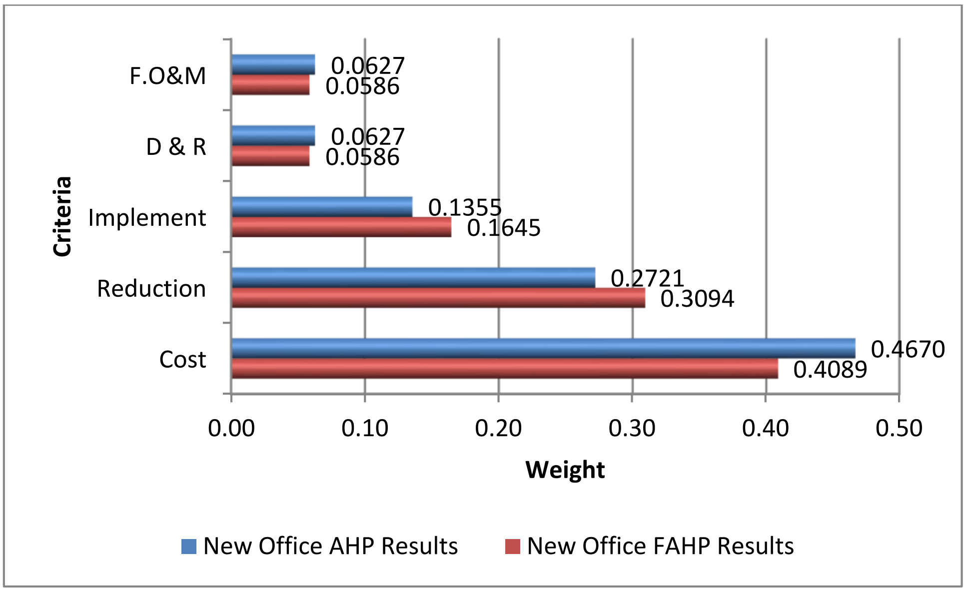


Figure 6.29 Opinion of contractors on criteria of new office using AHP and FAHP

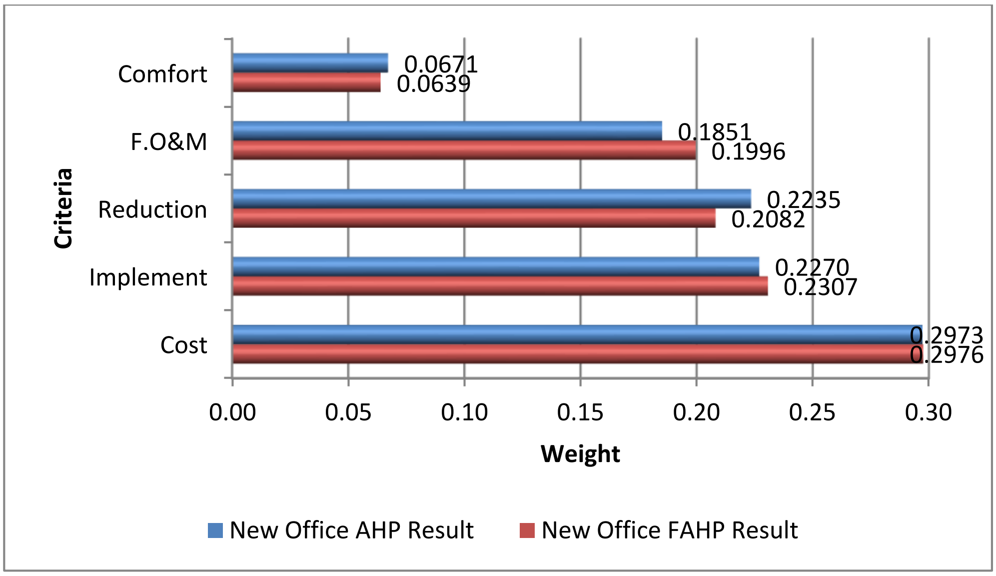


Figure 6.30 Opinion of owners on criteria of new office using AHP and FAHP

According to the responses of the experts of the four groups, a set of important criteria was identified. Some of the criterion were commonly identified by all the groups while others were restricted to individual groups. For example cost, reduction in consumption, and ease of implementation were commonly identified as important criteria by all the groups while comfort, impact, durability and reliability, and flexibility of operations and maintenance were identified by a subset of the groups.

In Figure 6.27 – Figure 6.30 show the results for assigning different weights to each criteria for new office buildings. As discussed above, these criteria are similar to those proposed in the case of existing office buildings. Similarly, no change is observed in the weights of consultant and contractor groups. This could be attributed to the limited number of experts in each group.

The results presented in Figure 6.27 – Figure 6.30 show that most of the experts in all the groups agree that reduction in consumption was one of the most important criteria for the selection of different DSM alternatives in new office building. Academics and consultants deem it particularly important as they give it the highest weights ($W_{AHP=36.26\%}$, $W_{FAHP=35.12\%}$) and ($W_{AHP=37.64\%}$, $W_{FAHP=36.24\%}$) respectively and rank it the most important criterion. On the other hand, contractors rank it in second level with a percentage weight of ($W_{AHP=27.21\%}$, $W_{FAHP=30.94\%}$) while owners rank it at the third level with a weight of ($W_{AHP=22.35\%}$, $W_{FAHP=20.82\%}$). This can be attributed to the similar reasoning presented earlier i.e., a possible motivation behind the selection of reduction of consumption as the most important criteria by the experts could be to reduce the running costs of using electricity. Another possible motivation could be to help to reduce the load on power generation facilities in the country or to reduce the effect of energy use on the environment. The latest is particularly true in the case of academics who are generally more aware of the impact of energy consumption on the environment. This fact is reflected in their assignment of the highest rank to the reduction in consumption criteria.

Cost was another criterion identified as important by all the groups. Contractors and owners place it as the top priority by assigning it weights of ($W_{AHP=46.7\%}$, $W_{FAHP=40.89\%}$) and ($W_{AHP=29.73\%}$, $W_{FAHP=29.76\%}$) respectively. On the other hand, academics rank it in the fourth level with relatively low percentage weight of ($W_{AHP=12.55\%}$, $W_{FAHP=12.54\%}$) while consultants consider it in the third level with similar percentage of ($W_{AHP=12.08\%}$, $W_{FAHP=12.63\%}$). Again, this could be motivated by similar reasons as were presented earlier in Section 6.4.1. i.e., it is possible that contractors and owners have higher stakes in the cost of the new potential DSM technology from business point of view. For example, capital cost is considered as a major criterion for economic evaluation as projects have constraints regarding budget allocations. Capital spending including installation expenditure requirements evaluation addresses the financial feasibility of the DSM options that need to be considered in the DSM selection process.

Ease of implementation was the third criteria that was commonly identified by all the four groups of experts. While it is understandably important for consultants and owners who rank it second by assigning it percentage weights of ($W_{AHP=30.62\%}$, $W_{FAHP=32.34\%}$) and ($W_{AHP=22.7\%}$, $W_{FAHP=23.07\%}$) respectively, surprisingly, academics also consider it the second most important criteria with a weight of ($W_{AHP=21.39.7\%}$, $W_{FAHP=22.48\%}$). On the other hand, contractors consider it in the third level with a percentage weight of ($W_{AHP=13.55\%}$, $W_{FAHP=16.45\%}$).

The flexibility of operation and maintenance criteria for the candidate DSM technology was deemed somewhat important by all the groups except that of academics. This can be explained by a possible lack of interest of academics in any operation and maintenance work as it is not their responsibility. On the other hand, consultants, contractors and owners assign the following percentage weights to this criteria: ($W_{AHP=10.80\%}$, $W_{FAHP=10.08\%}$), ($W_{AHP=6.27\%}$, $W_{FAHP=5.86\%}$), and ($W_{AHP=18.51\%}$, $W_{FAHP=19.96\%}$). The criterion is important to them possibly because they are responsible (in one way or the other) for performing tasks related to operation and maintenance.

The least important criterion for academics and owners was the comfort for users with weights of ($W_{AHP=10.64\%}$, $W_{FAHP=9.97\%}$) and ($W_{AHP=6.71\%}$, $W_{FAHP=6.39\%}$) respectively. On the other hand, the least important criterion for consultants and contractors was the durability and reliability of the DSM option they assigned it weights of ($W_{AHP=8.86\%}$, $W_{FAHP=8.71\%}$) and ($W_{AHP=6.27\%}$, $W_{FAHP=5.86\%}$) respectively.

It is important to note that the opinion of the experts of the four groups regarding the selection criteria for different DSM alternatives remained largely unchanged compared to their opinions for the existing office buildings. The only difference in opinion that was found, was in the opinions of the owners who seem to be more sensitive to easier implementation in new office buildings compared to existing office buildings. The consistency is also found in the results of both AHP and FAHP methods which suggests that, in this particular case, the use of FAHP does not provide any significant gains over the use of AHP.

6.5.2 Analysis of the results for DSM alternatives for new office buildings

Figure 6.31 – Figure 6.34 show the relative weights assigned by the four groups of experts using AHP and FAHP methods.

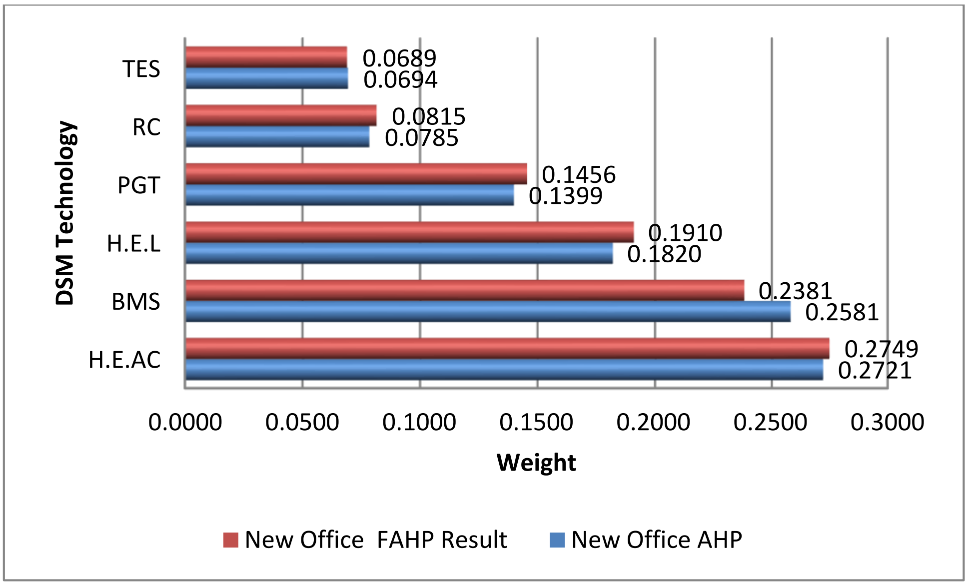


Figure 6.31 Opinion of academics on the DSM alternatives of new office using AHP and FAHP

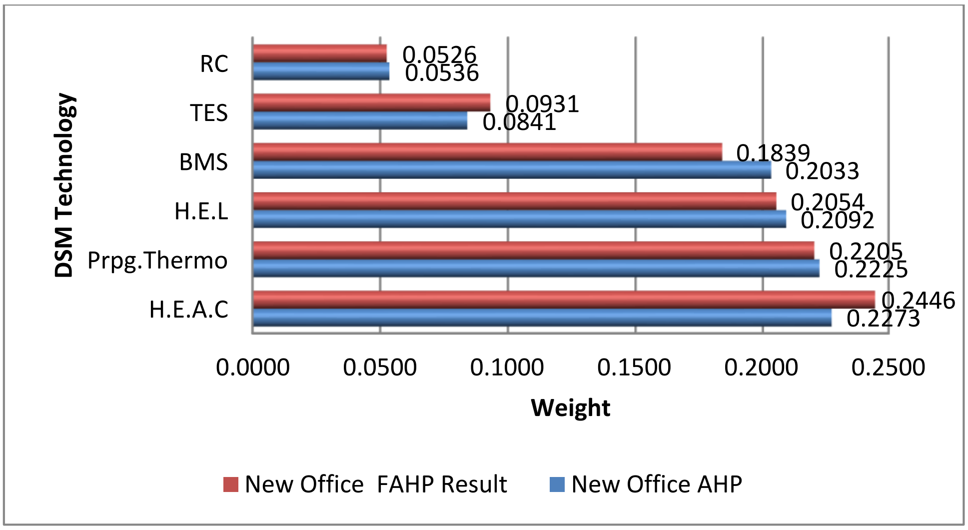


Figure 6.32 Opinion of consultants on the DSM alternatives of new office using AHP and FAHP

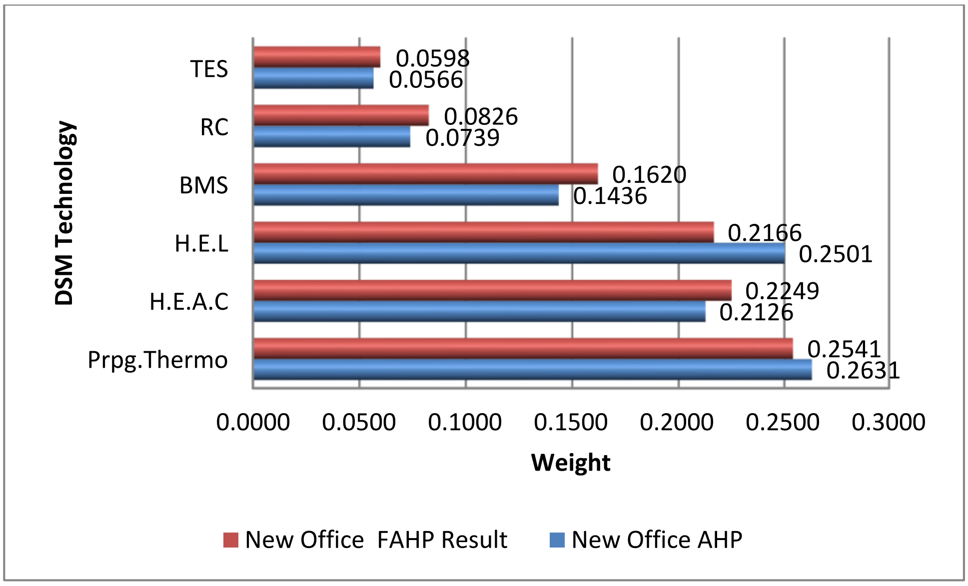


Figure 6.33 Opinion of contractors on the DSM alternatives of new office using AHP and FAHP

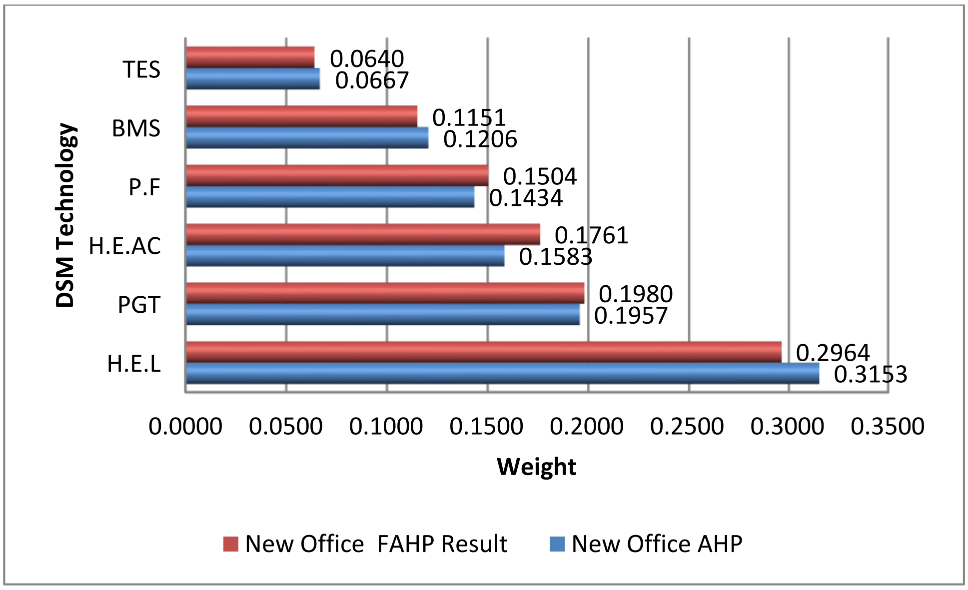


Figure 6.34 Opinion of owners on the DSM alternatives of new office using AHP and FAHP

Figure 6.31 – Figure 6.34 show that most of the experts in academics and consultants groups agree that high efficiency air conditioning is the best DSM option for new office buildings. On the other hand, owners support this option as the second best among the six DSM alternatives. This makes sense since owners are generally expected to be more sensitive to cost, hence they seem to prefer the low-cost option of high efficiency

lighting over the relatively expensive option of high efficiency air conditioning. The contractors ranked this option in the third place according to AHP and in the second place according to FAHP.

Academic experts recommended building management system as the second option followed by high efficiency lighting, the academic experts ranked thermal energy storage and remote control for air conditioning as the lowest recommended options. The analysis of the pairwise judgments of academic group regarding the selection of the optimal DSM in new office building is considerably robust, as it was found to have an inconsistency ratio of less than 0.1.

Consultant experts recommended programmable thermostats for air conditioning as the second option followed by the high efficiency lighting, building management system in the fourth rank while remote control for air conditioning system and thermal energy storage are the less appropriate DSM options from the consultants point view. The analysis of the pairwise judgments of consultants group regarding the selection of the optimal DSM in new office buildings is considerably robust, as it was found to have an inconsistency ratio less than 0.1.

Most of the experts in the consultant, owner and contractor groups agreed that a programmable thermostat for air condition has high importance. For example contactors experts consider the maximum weight ($W_{AHP=25.41\%}$, $W_{FAHP=26.31\%}$) for programmable thermostat option, also consultants and owners consider it as the second option with weights of ($W_{AHP=22.05\%}$, $W_{FAHP=22.25\%}$) and ($W_{AHP=19.8\%}$, $W_{FAHP=19.57\%}$) respectively while the academics consider less weight for programmable thermostats by ($W_{AHP=14.56\%}$, $W_{FAHP=13.99\%}$). This may be because academic group consider the feature of programmable thermostats could be provided in new building management system as this option is preferred in academics group more than other groups.

Contractor experts recommended high efficiency lighting as a second option and building management system in the fourth rank while remote control for air conditioning system and thermal energy storage are the less appropriate DSM options from the contractors' point of view. The analysis of the pair wise judgments of contractors group regarding the selection of the optimal DSM in new office buildings is considerably robust, as it was found to have an inconsistency ratio of less than 0.1.

Owner experts recommended high efficiency lighting as the first option and assigned it a weight of ($W_{AHP=31.53\%}$, $W_{FAHP=29.64\%}$) which is the maximum weight given among the other DSM options and this could be justified by the nature of building occupancy as partial occupancy, with consideration of proper selection of high efficiency lighting and proper control for lighting. Hence, this option is highly favourable.

Owner experts recommended power factor correction as an option in new office buildings in the fourth rank and eliminated the remote control for air conditioning. A reason for this could be that as remote control is an emerging technology that considers demand response control system and experts from the owner group are less aware of this technology compared to experts from the consultants, contractor and academic groups.

Owner experts also believe that building management system and thermal energy storage are the less appropriate DSM options. The analysis of the pairwise judgments of owner group regarding the selection of the optimal DSM technology in new office buildings is considerably robust, as it was found to have an inconsistency ratio of less than 0.1.

An interesting observation here was that, compared to existing office buildings in which academics and consultants did not look favourably at the option of high efficiency air conditioning, for new office buildings, they ranked it their top most priority. This could perhaps be explained by the fact that changing the whole air conditioning system in existing buildings would involve a lot of labour and cost while for new buildings, high efficiency air conditioning can be incorporated into the design and budget early on.

6.6 Analysis of the results for existing school buildings

In this section, a graphical comparison between the weights of AHP and FAHP will be presented for both criteria and DSM alternatives of existing school buildings where the results from all groups of experts will be introduced and discussed.

6.6.1 Comparison of the results obtained for the criteria for existing school buildings

The weights assigned for different criteria for selecting DSM alternatives for existing school buildings are shown in Figure 6.35 – Figure 6.38. The weights assigned using both AHP and FAHP are shown in these figures.

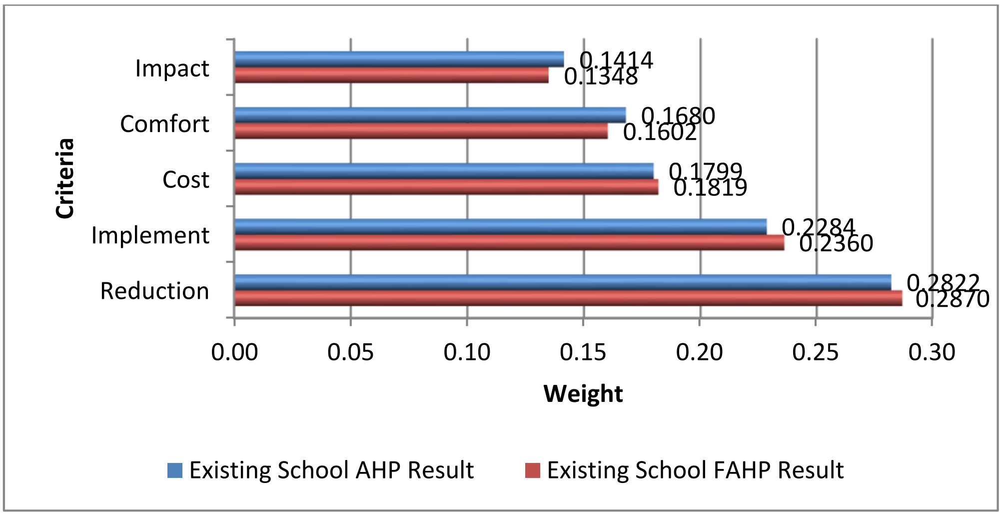


Figure 6.35 Opinion of academics on criteria of existing schools using AHP and FAHP

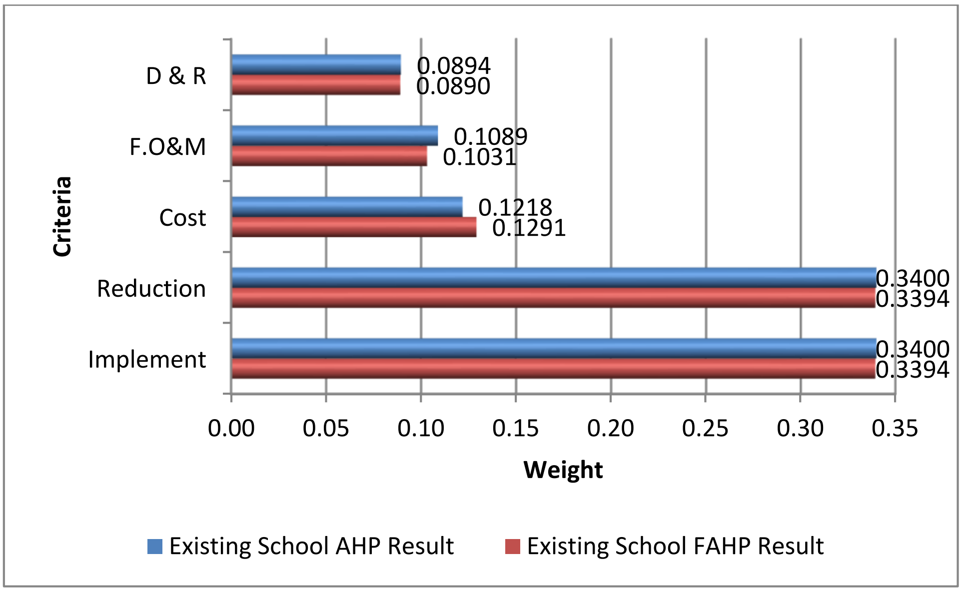


Figure 6.36 Opinion of consultants on criteria of existing schools using AHP and FAHP

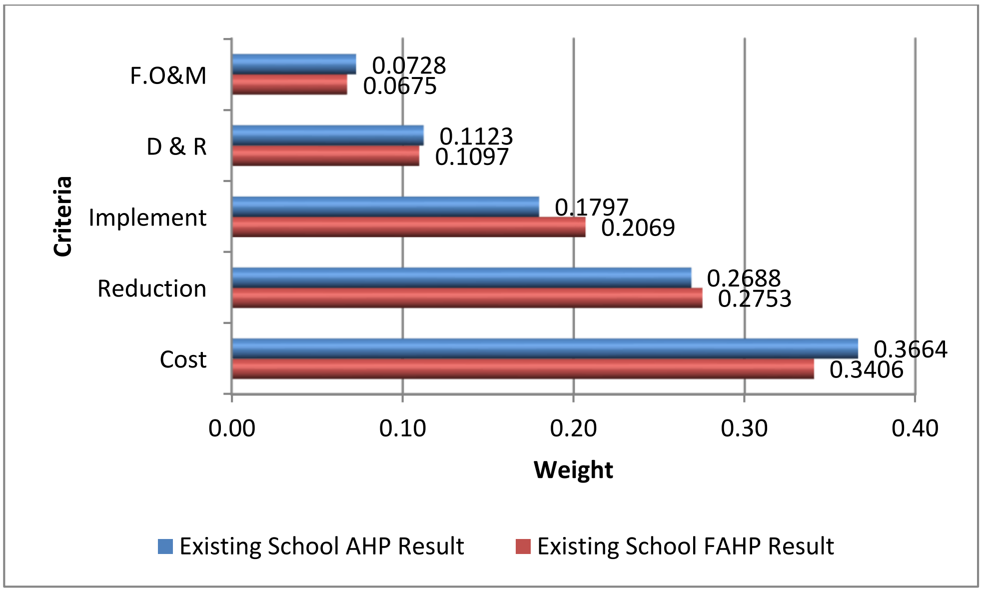


Figure 6.37 Opinion of contractors on criteria of existing schools using AHP and FAHP

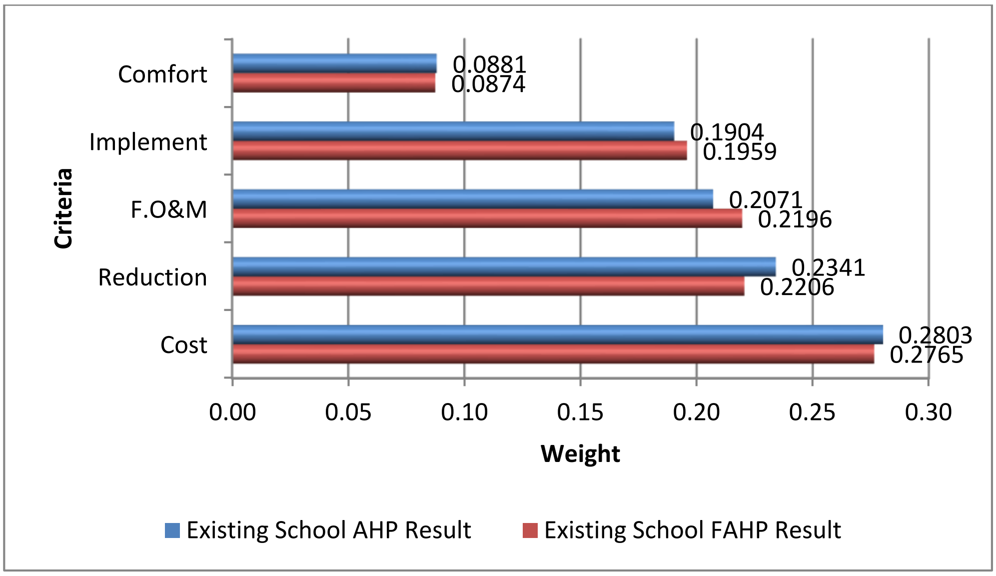


Figure 6.38 Opinion of owners on criteria of existing schools using AHP and FAHP

Figure 6.35 – Figure 6.38 show that most of the experts in all the groups agreed that reduction in consumption is the most important criteria for the selection of DSM alternatives in existing school buildings. Academics assigned a weight of ($W_{AHP=28.22\%}$, $W_{FAHP=28.70\%}$) which is the maximum weight given among the other criteria while consultants, contractors and owners consider it the second most important criteria with

weights of ($W_{AHP=34\%}$, $W_{FAHP=33.94\%}$), ($W_{AHP=26.88\%}$, $W_{FAHP=27.53\%}$) and ($W_{AHP=23.41\%}$, $W_{FAHP=22.06\%}$) respectively. A reason for the higher consideration of academics towards reduction in consumption compared to other groups of experts could be that while reduction in consumption will not only lead to a reduction in cost for the users which is of interest to all the experts but will also reduce the pressure on the government to generate more energy and will possibly reduce carbon emissions which can benefit the whole planet. The last advantage is usually more appreciated by the academics who are generally more aware of global problems.

Cost criterion is considered by contractors and owners as the most important criteria with percentage weights of ($W_{AHP=36.64\%}$, $W_{FAHP=34.06\%}$) and ($W_{AHP=28.03\%}$, $W_{FAHP=27.65\%}$) respectively, while academics and consultants rank it in the third place with relatively smaller percentage weights of ($W_{AHP=17.99\%}$, $W_{FAHP=18.19\%}$) and ($W_{AHP=12.18\%}$, $W_{FAHP=12.91\%}$) respectively. A possible motivation for this could be the higher stakes (from business point of view) of contractors and owners in the cost of the new DSM technology as capital cost is generally considered as major criterion for economic evaluation and projects have constraints about budget allocations. Capital spending including installation expenditure requirements evaluation addresses the financial feasibility of the DSM options that need to be considered in the DSM selection process.

Ease of implementation criterion is recommended by all the groups of experts. Academics and consultants consider it in the second place with percentage weights of ($W_{AHP=28.84\%}$, $W_{FAHP=40.89\%}$) and ($W_{AHP=34\%}$, $W_{FAHP=33.94\%}$) respectively while contractors consider it in the third place with a percentage weight of ($W_{AHP=17.97\%}$, $W_{FAHP=20.69\%}$). On the other hand, the owners consider it in the fourth place among the proposed five criteria with a percentage of ($W_{AHP=19.04\%}$, $W_{FAHP=19.59\%}$).

Criterion of flexibility of operation and maintenance for the candidate DSM technology is recommended by consultants in the fourth place with a percentage weight of ($W_{AHP=10.89\%}$, $W_{FAHP=10.31\%}$), contractors in the fifth place with a percentage weight of ($W_{AHP=7.28\%}$, $W_{FAHP= 6.75\%}$) while owners rank it third with a percentage weight of ($W_{AHP=20.71\%}$, $W_{FAHP=21.96\%}$).

The least important criterion for academics was the impact on environment with a weight of ($W_{AHP=14.14}$, $W_{FAHP=13.48\%}$). On the other hand, the least important criterion for consultants was the durability and reliability of the DSM option with a weight of ($W_{AHP=8.94\%}$, $W_{FAHP=8.9\%}$) while the least important criterion for owners was the comfort for users with a weight of ($W_{AHP=8.81\%}$, $W_{FAHP=8.74\%}$). Flexibility of operation and maintenance criterion was the least important criterion for contractors with a weight of ($W_{AHP=7.28\%}$, $W_{FAHP=6.75\%}$).

It is important to note that both AHM and FAHM obtained similar results across all the four groups.

6.6.2 Analysis of the results for DSM alternatives for existing school buildings

Figure 6.39 – Figure 6.42 show the relative weights obtained using AHP and FAHP for the selection of a DSM alternative for existing school buildings. The weights are based on the responses of experts from the four groups of academics, consultants, contractors and owners.

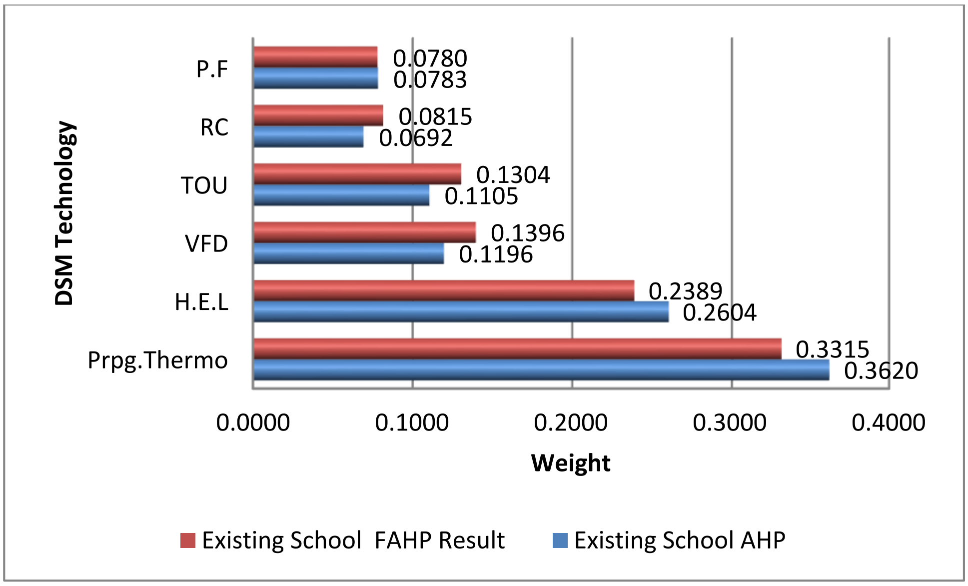


Figure 6.39 Opinion of academics on the DSM alternatives for existing schools using AHP and FAHP

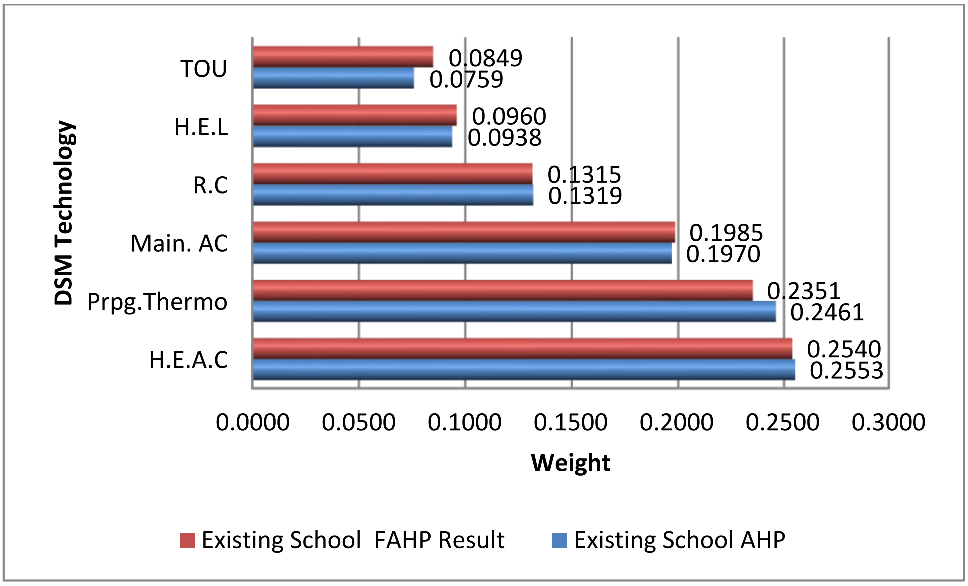


Figure 6.40 Opinion of consultants on the DSM alternatives for existing schools using AHP and FAHP

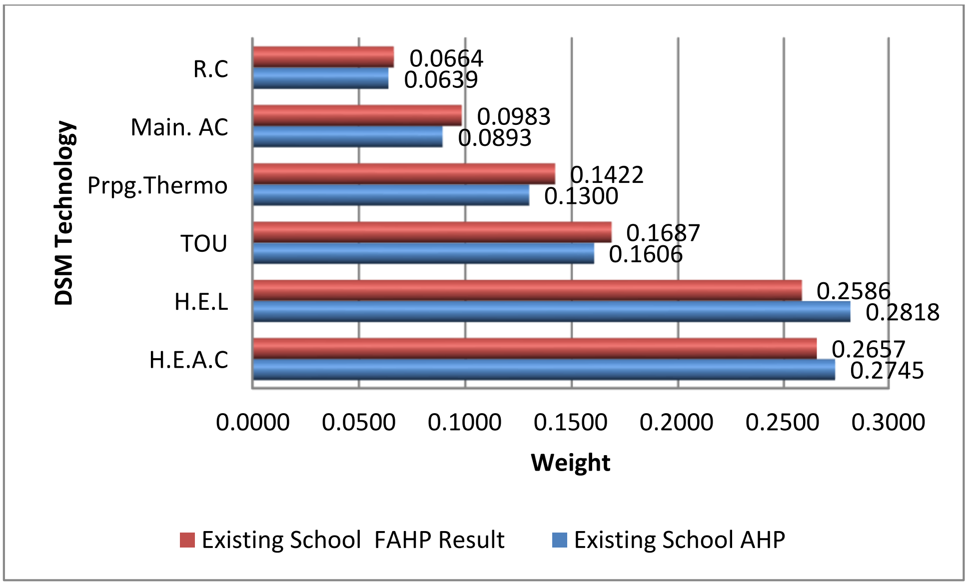


Figure 6.41 Opinion of contractors on the DSM alternatives for existing schools using AHP and FAHP

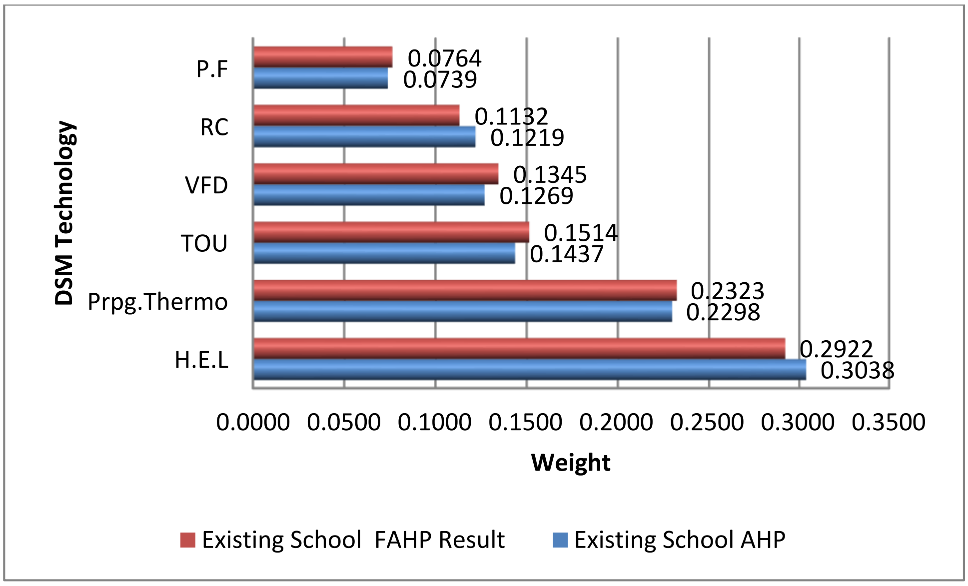


Figure 6.42 Opinion of owners on the DSM alternatives for existing schools using AHP and FAHP

In Figure 6.39, according to the results obtained using AHP, power factor correction was ranked fifth by the academics while considering the available DSM alternatives. Remote control A/C was ranked as the last option. Figure 6.39 also shows that the programmable thermostat for air conditioning system was regarded by the academic experts as the best DSM option for existing school buildings, followed by high efficiency lighting (H.E.L) and variable frequency drive for A/C system (VFD), the academic experts ranked power factor correction devices and remote control (RC) for air conditioning as the least recommended options for AHP results. After implementing FAHP, some of the ranks changed for academic group as power factor correction with AHP was fifth in academics groups, whereas in FAHP, it is ranked sixth. The remote control is ranked sixth in AHP results, whereas in FAHP ranked it fifth.

In Figure 6.41, according to the results obtained using AHP, high efficiency lighting was regarded by the contractors as the best DSM option for existing school buildings, followed by high efficiency A/C and time of use control options. It is interesting to note that high efficiency lighting was ranked first by AHP, whereas the FAHP ranked it second.

Programmable thermostat was considered as the best option for academics with a percentage weight of ($W_{AHP=36.20\%}$, $W_{FAHP=33.15\%}$) and was considered as the second best option for consultants and owners with percentage weights of ($W_{AHP=24.61\%}$, $W_{FAHP=23.51\%}$) and ($W_{AHP=22.98.7\%}$, $W_{FAHP=23.23\%}$) respectively while contractors consider it as the fourth best DSM option with a percentage weight of ($W_{AHP=13\%}$, $W_{FAHP=14.22\%}$).

High efficiency lighting was considered as the most appropriate DSM option by contractors and owners with percentage weights of ($W_{AHP=28.18\%}$, $W_{FAHP=25.86\%}$) and ($W_{AHP=30.38\%}$, $W_{FAHP=29.22\%}$) respectively and was considered as the second best option by academics with a percentage of ($W_{AHP=26.04\%}$, $W_{FAHP=33.15\%}$) while consultants considered it as the second last DSM option with a percentage weight of ($W_{AHP=9.38\%}$, $W_{FAHP=9.6\%}$). Consultants recommended maintenance and remote control for air-conditioning rather than high efficiency lighting system and time of use control for lighting system which was regarded as the last DSM option for existing school buildings.

Most of the experts in academic, consultant and owner groups feel that remote control (RC) for air conditioning option is not highly recommended for existing school buildings.

Maintenance of air conditioning was recommended by consultants and contractors group only while academics and owners recommended power factor correction devices installation and variable frequency drives for air conditioning systems.

The analysis of the pairwise judgments of academics, contractors and owner groups regarding the selection of the optimal DSM in new school buildings is considerably robust, as it has an inconsistency ratio of less than 10%.

It is to be noted that while the results obtained using AHP and FAHP are largely consistent. There were two notable exceptions, though. One, according to AHP, academics seem to favour power factor correction over remote control for air conditioning, while according to FAHP, they favour remote control for air conditioning over power factor correction. Two, according to AHP, contractors favour high efficiency lighting over high efficiency air conditioning, while according to FAHP, they favour high efficiency air conditioning over high efficiency lighting. The choice of high efficiency air conditioning over high efficiency lighting by contractors can be justified with the same reasoning as in Section 6.3.2.

6.7 Analysis of the results for new school buildings

In this section, a graphical comparison between the weights of AHP and FAHP will be presented for both criteria and DSM alternatives of new school buildings where the results from all groups of expert will be introduced and discussed.

6.7.1 Comparison of the results obtained for the criteria for new school buildings

Figures in this section represent AHP and FAHP relative weights results of DSM criteria for new school buildings for all groups of experts who participated in the questionnaire of this research phase.

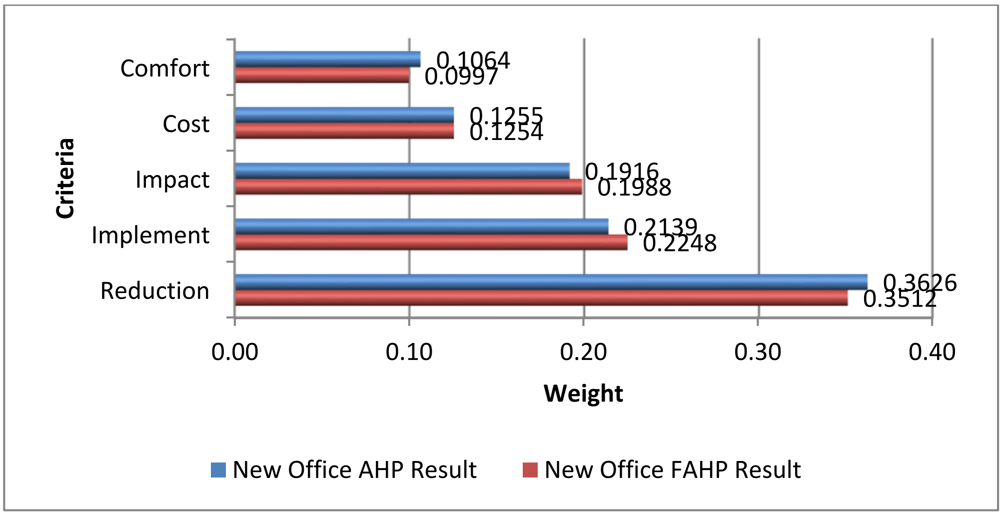


Figure 6.43 Opinion of academics on criteria of new schools using AHP and FAHP

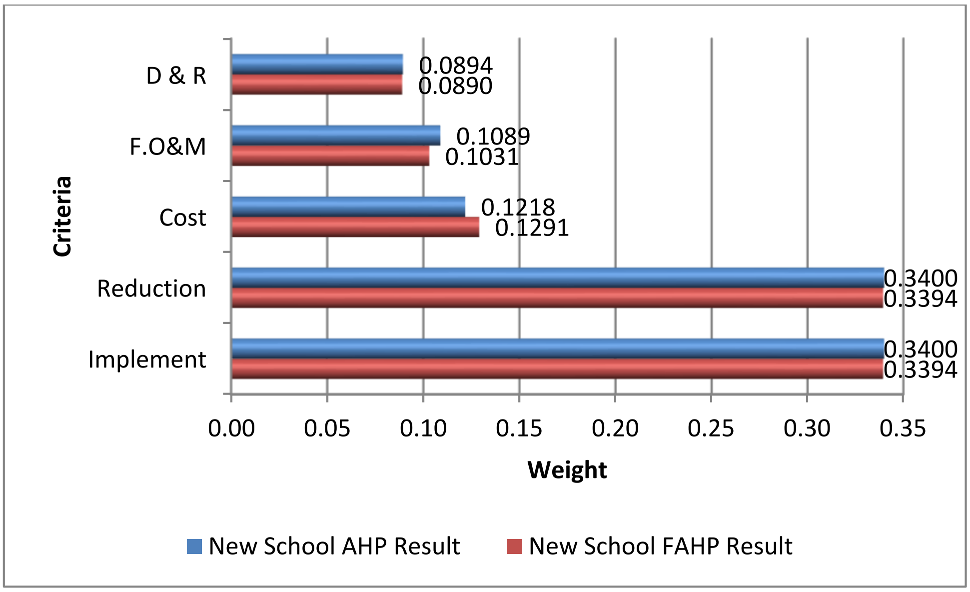


Figure 6.44 Opinion of consultants on criteria of new schools using AHP and FAHP

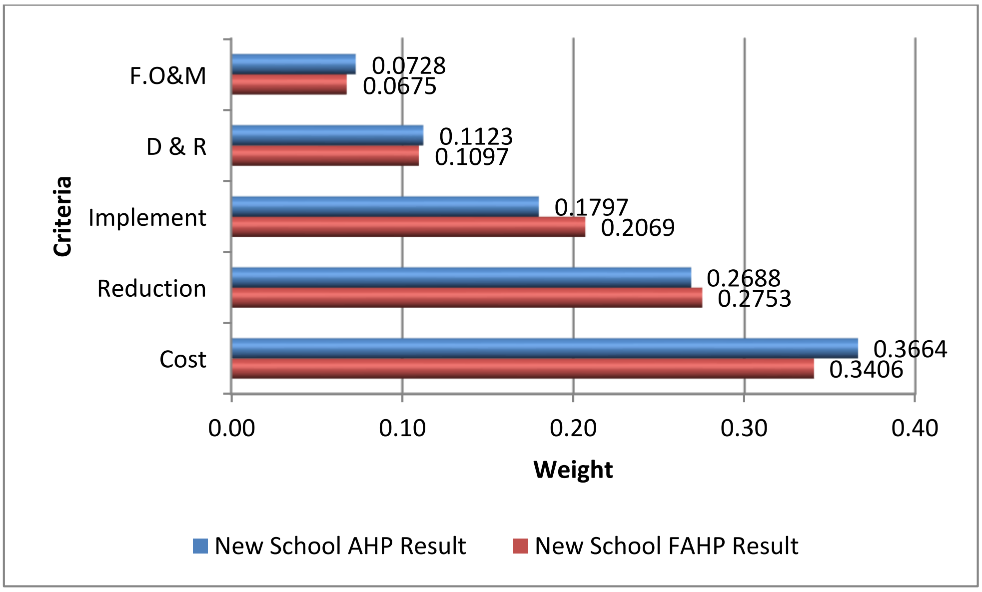


Figure 6.45 Opinion of contractors on criteria of new schools using AHP and FAHP

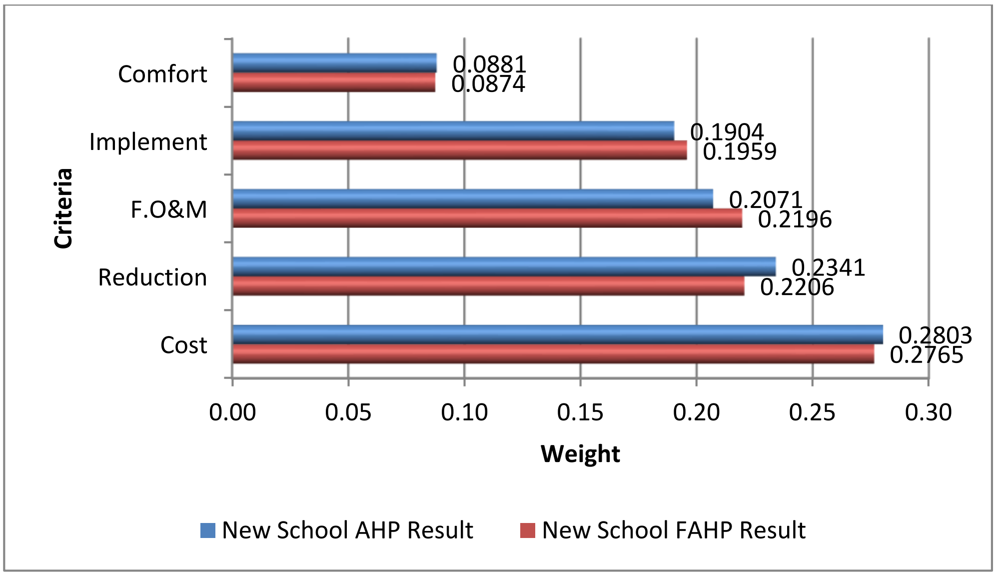


Figure 6.46 Opinion of owners on criteria of new schools using AHP and FAHP

Figure 6.43 shows that the first three criteria have been ranked by both AHP and FAHP methods while the fourth and fifth positions are different for AHP and FAHP. For example, comfort criterion was the fourth according to AHP, whereas according to FAHP, it is ranked fifth.

Results in previous figures show that the experts in all groups agree that reduction in consumption is the recommended criteria for selection of DSM alternatives in new school buildings. Academic and consultant experts gave the highest weights of ($W_{AHP=28.92\%}$, $W_{FAHP=27.71\%}$), ($W_{AHP=46.7\%}$, $W_{FAHP=40.89\%}$) and ($W_{AHP=34\%}$, $W_{FAHP=33.94\%}$) respectively and ranked it as most important criterion. Contractors and owners rank it as the second best with percentage weights of ($W_{AHP=26.88\%}$, $W_{FAHP=27.53\%}$) and ($W_{AHP=23.41\%}$, $W_{FAHP=22.06\%}$) respectively.

The rationale for these weights can be explained using similar reasons as given in Section 6.3.

Cost criteria is recommended by contractors and owners as the most important criterion with percentage weights of ($W_{AHP=36.64\%}$, $W_{FAHP=34.06\%}$) and ($W_{AHP=28.03\%}$, $W_{FAHP=27.65\%}$) respectively, while academics and consultants rank it in the third position with relatively medium percentage weights of ($W_{AHP=18.02\%}$, $W_{FAHP=18\%}$) and ($W_{AHP=12.18\%}$, $W_{FAHP=12.91\%}$) respectively. Capital spending including installation expenditure requirements evaluation addresses the financial feasibility of the DSM options that need to be consider in the DSM selection process.

While ease of implementation criteria is recommended by all groups of experts, academics and consultants consider it in the second level with percentage weights of ($W_{AHP=22.06\%}$, $W_{FAHP=24.34\%}$) and ($W_{AHP=34\%}$, $W_{FAHP=33.94\%}$) respectively while contractors consider it in the third level with a percentage weight of ($W_{AHP=17.97\%}$, $W_{FAHP=20.69\%}$) and owners group consider it in the fourth level among the proposed five criteria with a percentage weight of ($W_{AHP=19.04\%}$, $W_{FAHP=19.59\%}$).

The criterion of flexibility of operation and maintenance for the candidate DSM technology is recommended by consultants in the fourth level with a percentage weight of ($W_{AHP=10.89\%}$, $W_{FAHP=10.31\%}$), by contractors in the fifth level with a percentage weight of ($W_{AHP=7.28\%}$, $W_{FAHP=6.75\%}$) and by owners in the third level with a percentage weight of ($W_{AHP=20.71\%}$, $W_{FAHP=21.96\%}$).

The least important criterion among the listed five criteria for academics and owners was comfort to users with weights of ($W_{AHP=16.75\%}$, $W_{FAHP=14.46\%}$) and ($W_{AHP=8.81\%}$, $W_{FAHP=8.74\%}$) respectively. On the other hand, the least important criterion for consultants was the durability and reliability of the DSM option with a weight of ($W_{AHP=8.94\%}$, $W_{FAHP=8.9\%}$). Flexibility of operation and maintenance criterion was the least important criterion for contractors with a weight of ($W_{AHP=7.28\%}$, $W_{FAHP=6.75\%}$).

It is important to note that the results were largely consistent with those obtained for existing schools. One exception was the position of the impact and comfort criteria for the academics. Though the results for these criteria seemed consistent with the results for existing schools when AHP was used, for FAHP, the positions of these two criteria swapped.

6.7.2 Analysis of the results for DSM alternatives for new school buildings

Figures in this section represent AHP and FAHP relative weights results of DSM alternatives of new school buildings for all groups of experts who participated in the questionnaire of this research phase.

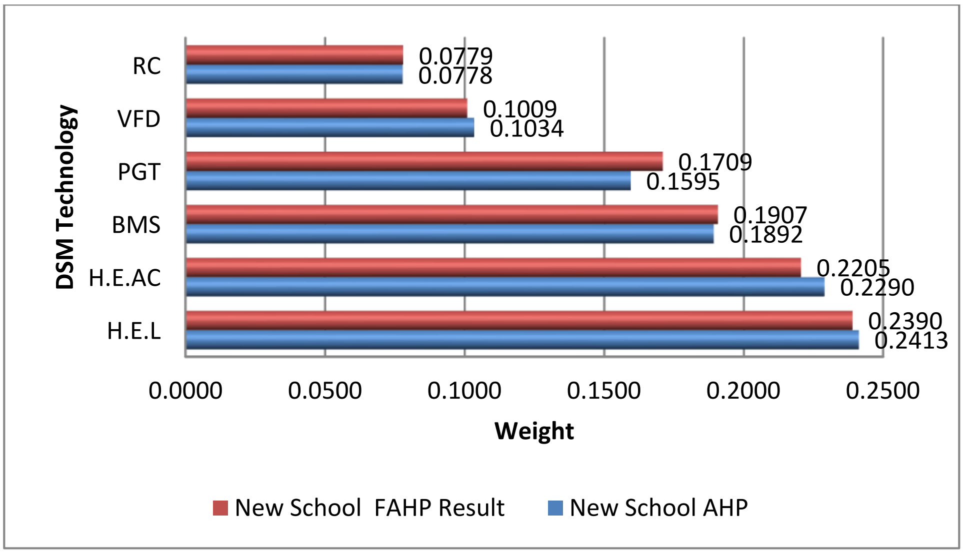


Figure 6.47 Opinion of academics on the DSM alternatives of new schools using AHP and FAHP.

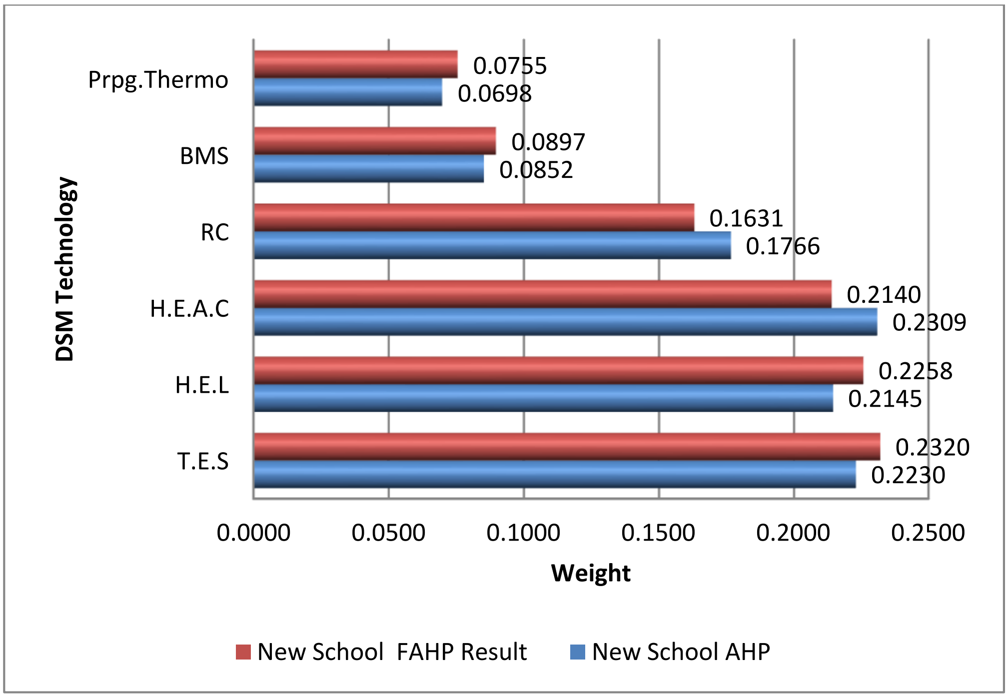


Figure 6.48 Opinion of consultants on the DSM alternatives of new schools using AHP and FAHP

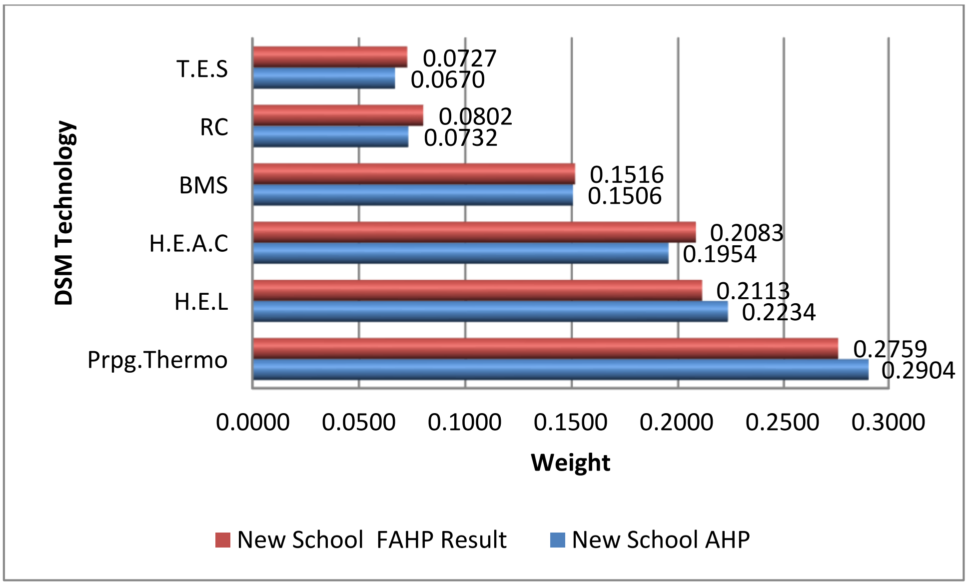


Figure 6.49 Opinion of contractors on the DSM alternatives of new schools using AHP and FAHP

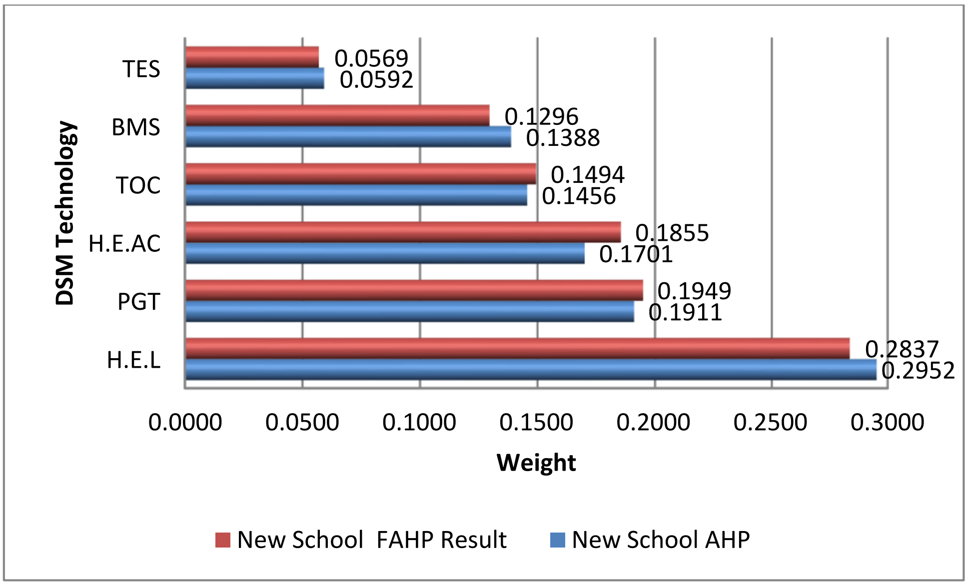


Figure 6.50 Opinion of owners on the DSM alternatives of new schools using AHP and FAHP

In Figure 6.48, according to the results obtained using AHP, high efficiency air conditioning was regarded by the consultants as being the most important DSM option for new school buildings, followed by thermal energy storage air conditioning and high efficiency lighting options. It is interesting to note that some of the ranks change when

FAHP is used instead of AHP. For example, FAHP ranked thermal energy storage first, followed by high efficiency lighting and high efficiency air conditioning options.

Figure 6.47 – Figure 6.50 show that all the experts agree that designing new school buildings with high efficiency lighting can be considered as the most appropriate DSM option. A reason for this can be that it is expected to be a cost-effective option and is expected to be easily integratable into the design of new school buildings. Academics and owners consider it as the first option with percentage weights of ($W_{AHP=24.13\%}$, $W_{FAHP=23.9\%}$) and ($W_{AHP=29.52\%}$, $W_{FAHP=28.37\%}$) respectively. Contractors consider it as the second best option with a percentage of ($W_{AHP=22.34\%}$, $W_{FAHP=21.13\%}$). On the other hand, consultants consider it in the second place with a high percentage of ($W_{AHP=21.45\%}$, $W_{FAHP=22.58\%}$). A reason for this could be that installing new efficient equipment in new buildings is expected to be a cost-effective approach instead of installing low efficiency equipment. This justification is also supported by the opinion of all experts about installing high efficiency air conditioning system in new school buildings where this option is regarded by the consultant experts as the most recommended DSM option for new school buildings with a percentage weight of ($W_{AHP=23.09\%}$, $W_{FAHP=21.40\%}$) and academics consider it as second DSM option with a percentage weight of ($W_{AHP=22.9\%}$, $W_{FAHP=22.05\%}$). Contractors and owners consider it in the third place with percentage weights of ($W_{AHP=19.54\%}$, $W_{FAHP=20.83\%}$) and ($W_{AHP=17.01\%}$, $W_{FAHP=18.55\%}$) respectively.

Thermal energy storage is recommended by consultants as the second best option with a percentage weight of ($W_{AHP=22.30\%}$, $W_{FAHP=23.2\%}$) and last option by contractor and owner groups with percentage weights of ($W_{AHP=6.7\%}$, $W_{FAHP=7.27\%}$) and ($W_{AHP=5.92\%}$, $W_{FAHP=5.69\%}$) respectively. This option was not considered by academics group and was set to the lowest option. Consultants may believe that using thermal energy storage air conditioning contributes to the peak consumption in the country but this case is applicable only if air-conditioning systems are working in summer holidays.

Time of use control option is recommend by owners only and this could be substituted by using building management system option that can provide the features of time of use control for many types of equipment. Variable frequency drives of air-conditioning systems was also supported by the academic group only.

The analysis of the pair-wise judgments of academics, contractors and owner groups regarding the selection of the optimal DSM in new school buildings is considerably robust, as it was found to have an inconsistency ratio less than 0.1.

6.8 Analysis of the results for existing religious buildings

In this section, a graphical comparison between weights of AHP and FAHP will be presented for both criteria and DSM alternatives of existing religious building where the results from all groups of expert will be introduced and discussed.

6.8.1 Comparison of the results obtained for the criteria for existing religious buildings

Figures in this section represent AHP and FAHP relative weights results of DSM criteria of existing religious building for all groups of experts who participated in the questionnaire of this research phase.

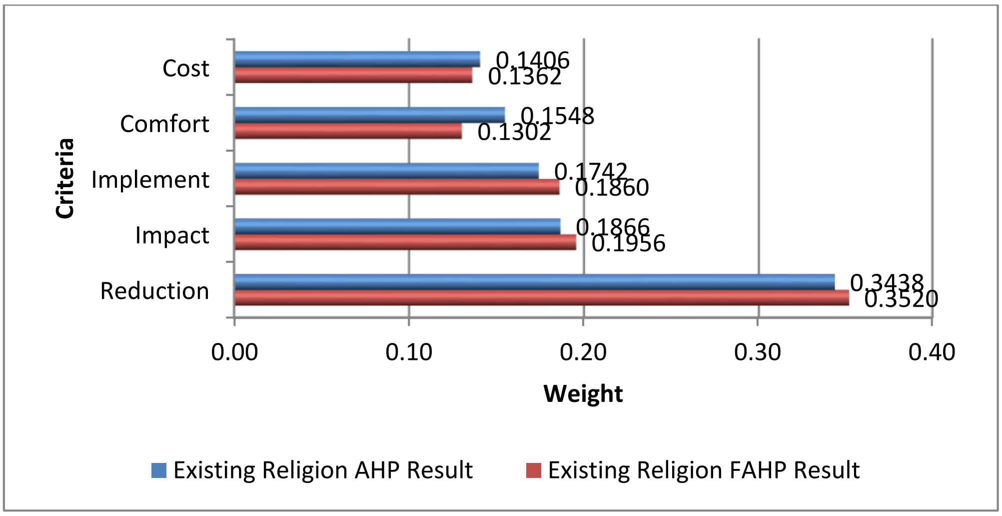


Figure 6.51 Opinion of academics on criteria of existing religious buildings using AHP and FAHP

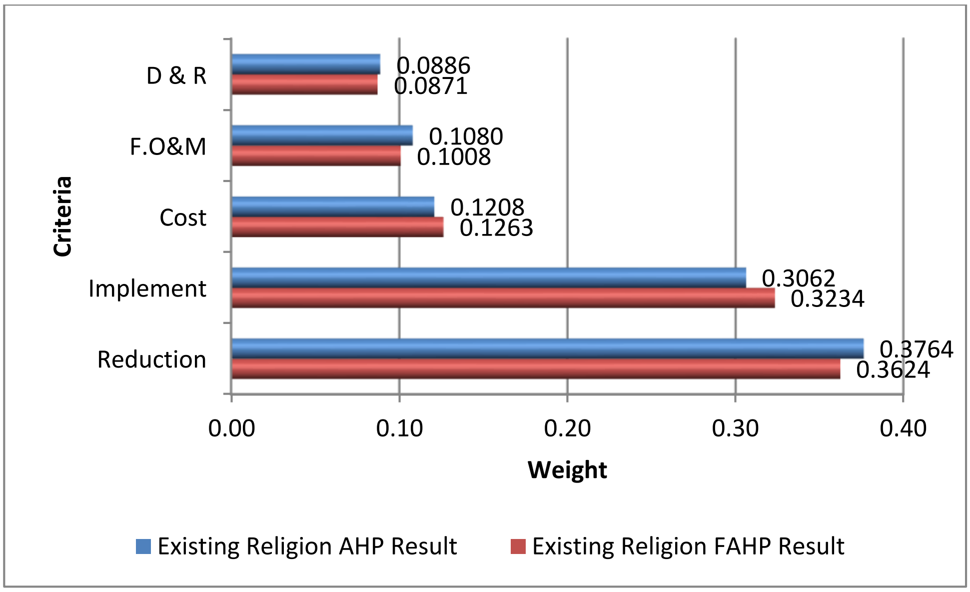


Figure 6.52 Opinion of consultants on criteria of existing religious buildings using AHP and FAHP

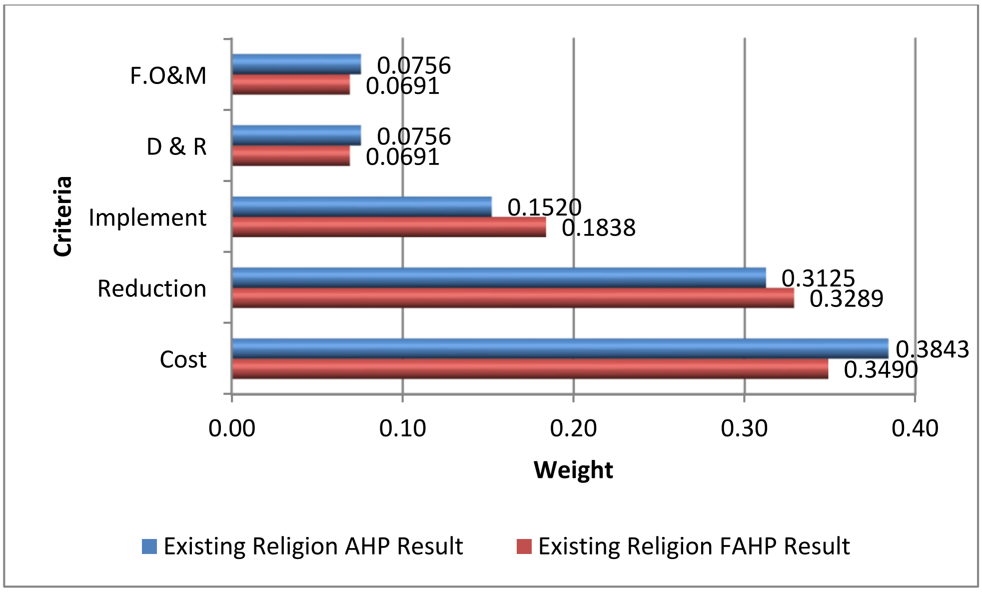


Figure 6.53 Opinion of contractors on criteria of existing religious buildings using AHP and FAHP

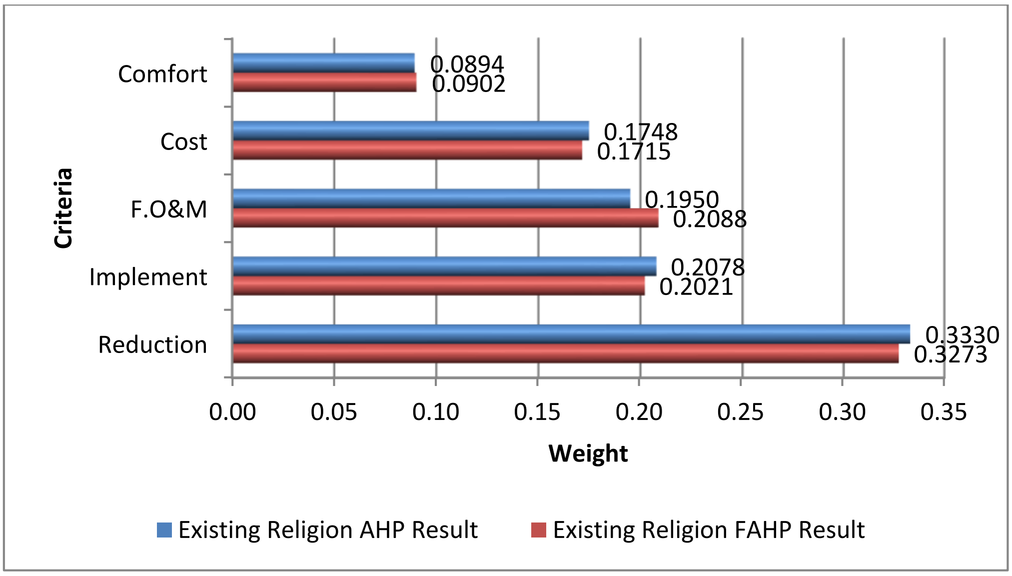


Figure 6.54 Opinion of owners on criteria of existing religious buildings using AHP and FAHP

Figure 6.51 shows that the first three criteria have been ranked by both AHP and FAHP methods while the fourth and fifth positions are different for AHP and FAHP. For example, comfort criterion was the fourth according to AHP, whereas according to FAHP, it is ranked fifth.

Also in Figure 6.54 there are some differences in the places, as ease of implementation criterion was the second in AHP analysis, whereas in the FAHP analysis is ranked third, the exchange in priorities was with flexibility of operation and maintenance.

Figures 6.51 – Figure 6.54 show that most of the experts in all groups agree that reduction in consumption is the recommended criteria for selection of DSM alternatives in new religious building. Academic, consultant and owner experts give the highest weights of ($W_{AHP=34.38\%}$, $W_{FAHP=35.2\%}$), ($W_{AHP=37.64\%}$, $W_{FAHP=36.24}$) and ($W_{AHP=33.3\%}$, $W_{FAHP=32.73\%}$) respectively and ranked it as the most important criterion, while contractors rank it in second level with percentage weight of ($W_{AHP=31.25\%}$, $W_{FAHP=32.89\%}$). Such favourable consideration for reduction in consumption by all the groups of experts can be explained with similar reasoning as was done in earlier sections.

Cost criterion is recommended by contractors as the most important criteria with a percentage weight of ($W_{AHP=38.43\%}$, $W_{FAHP=34.9\%}$), while academics rank it in the fourth level with a relatively low percentage weight ($W_{AHP=14.06\%}$, $W_{FAHP=13.62\%}$) and consultants consider it in the third level with a similar percentage weight ($W_{AHP=12.08\%}$, $W_{FAHP=12.63\%}$). Capital spending including installation expenditure requirements evaluation addresses the financial feasibility of the DSM options that need to be considered in the DSM selection process.

Ease of implementation criteria is recommended by all experts group. Academics, contractors and owners consider it in the third level with percentage weights of ($W_{AHP=17.42\%}$, $W_{FAHP=18.6\%}$), ($W_{AHP=15.20\%}$, $W_{FAHP=18.38\%}$), and ($W_{AHP=20.78\%}$, $W_{FAHP=20.21\%}$) respectively while consultants consider it in the second level with a percentage weight of ($W_{AHP=30.62\%}$, $W_{FAHP=32.34\%}$).

Criterion of flexibility of operation and maintenance for the candidate DSM technology is recommended by consultants, contractors and owners with percentage weights of ($W_{AHP=10.8\%}$, $W_{FAHP=10.08\%}$), ($W_{AHP=7.56\%}$, $W_{FAHP=6.91\%}$), and ($W_{AHP=19.5\%}$, $W_{FAHP=20.88\%}$) respectively. This criteria is proposed due the importance of the simplicity of operation and maintenance for a DSM technology.

The least important criterion for academics and owners was comfort to users with weights of ($W_{AHP=15.48\%}$, $W_{FAHP=13.02\%}$) and ($W_{AHP=8.94\%}$, $W_{FAHP=9.02\ \%}$). On the other hand, the least important criterion for consultants and contractors was the durability and reliability of the DSM option with weights of ($W_{AHP=8.86\%}$, $W_{FAHP=8.71\%}$) and ($W_{AHP=7.56\%}$, $W_{FAHP=6.91\%}$).

It is important to note that for existing buildings that are used for religious purposes, the results obtained using both AHP and FAHP were largely consistent. Two important exceptions were observed in the opinions of the academics, who according to AHP, are more sensitive to comfort, while FAHP suggests they are more sensitive to the cost. Another exception was observed in the opinion of the owners, who, according to AHP are more sensitive to implementation compared to cost, while FAHP suggests otherwise.

6.8.2 Analysis of the results for DSM alternatives for existing religious buildings

Figures in this section represent AHP and FAHP relative weights results of DSM alternatives of existing religious buildings for all groups of experts who participated in the questionnaire of this research phase.

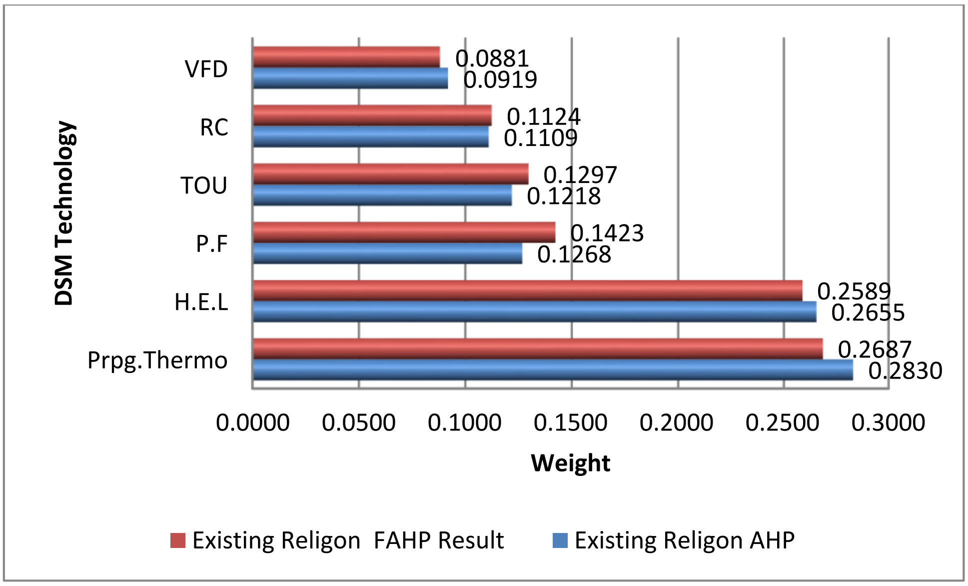


Figure 6.55 Opinion of academics on the DSM alternatives of existing religious building using AHP and FAHP

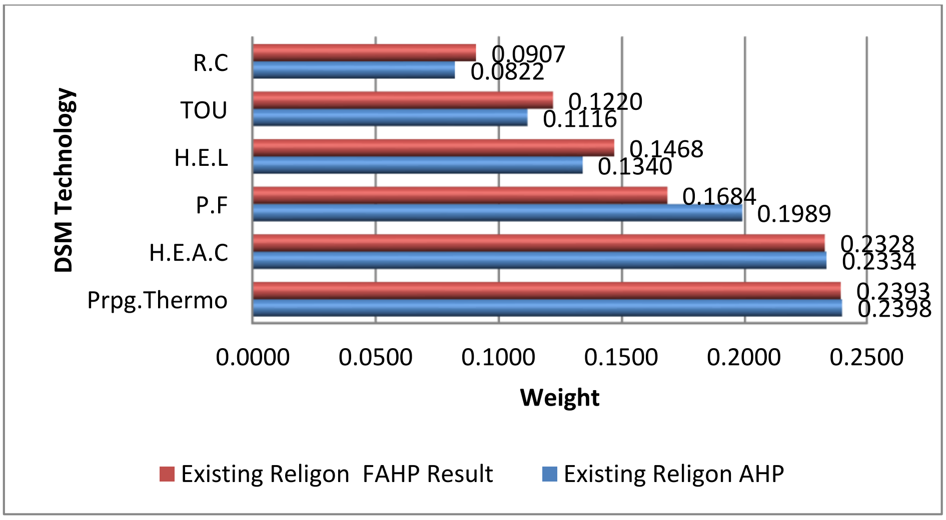


Figure 6.56 Opinion of consultants on the DSM alternatives of existing religious buildings using AHP and FAHP

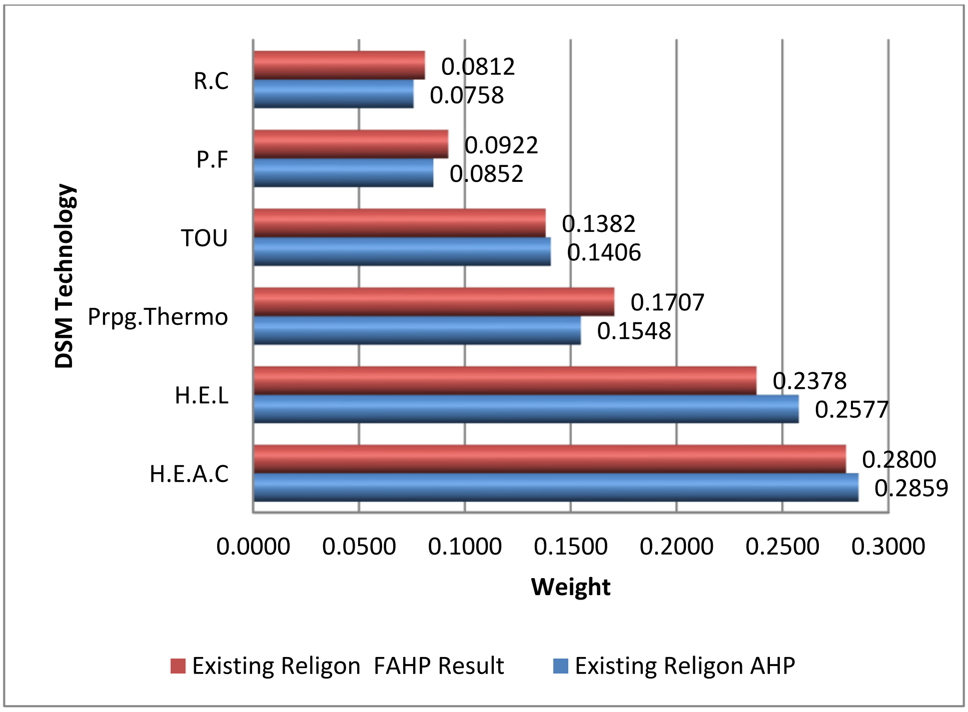


Figure 6.57 Opinion of contractors on the DSM alternatives of existing religious buildings using AHP and FAHP

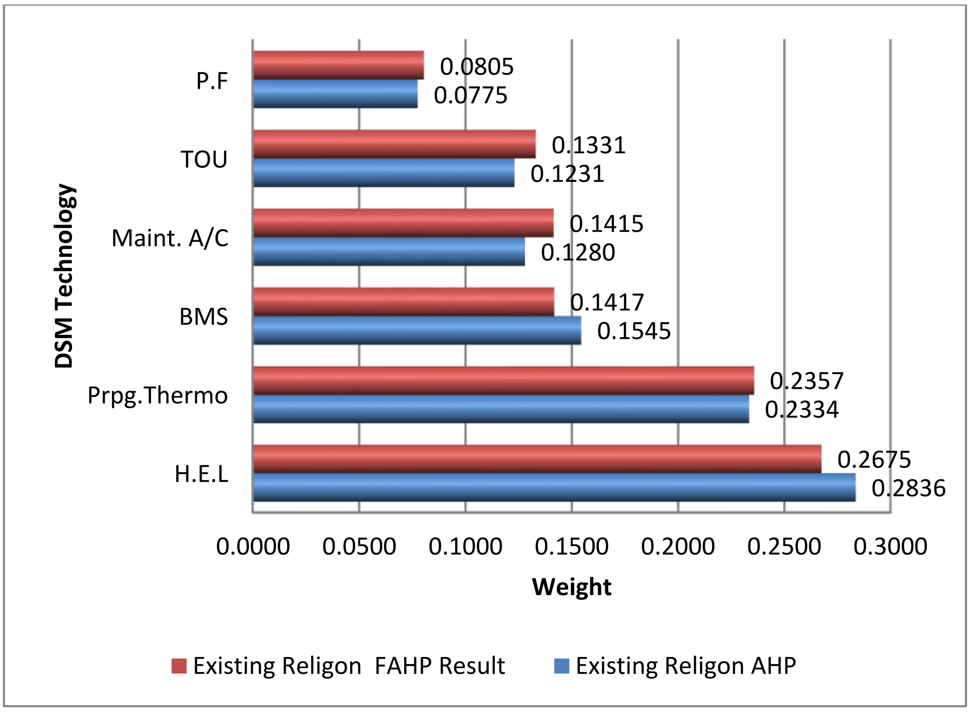


Figure 6.58 Opinion of owners on the DSM alternatives of existing religious buildings using AHP and FAHP

In Figure 6.57, according to the results obtained using AHP, high efficiency lighting was regarded by the contractors as the most important DSM option for existing religious buildings, followed by high efficiency A/C and programmable thermostat options. There are some changes in the ranks when the results are obtained using FAHP, as high efficiency lighting was first in AHP, whereas the FAHP rated it in second place and high efficiency A/C in the first.

Figure 6.55 shows the judgments of academic experts with respect to the importance of the DSM options in relation to the selection of the most optimal DSM in existing religious buildings. Retrofit of programmable thermostat for air-conditioning system was regarded by the academic experts as the most recommended DSM option for existing religious buildings, followed by high efficiency lighting, power factor correction devices, time of use control of lighting system. Remote control for air conditioning and variable frequency drive were the lowest recommended options.

Most of the experts in all the groups agree that programmable thermostat for air-conditioning system is recommended option in existing religious buildings. Academic and consultant experts give the highest weights ($W_{AHP=28.83\%}$, $W_{FAHP=26.87\%}$) and ($W_{AHP=23.98\%}$, $W_{FAHP=23.93\%}$) respectively and ranked it as the first option. Owners rank it as the second option with a percentage weight of ($W_{AHP=23.34\%}$, $W_{FAHP=23.57\%}$) while contractors rank it as the third option with a percentage weight of ($W_{AHP=15.48\%}$, $W_{FAHP=17.07\%}$).

Also, it is noticed that academics and owners have not included the option of retrofit high efficiency air conditioning in existing religious buildings due to the high capital cost of the option. While the contractors give this option the highest percentage weight ($W_{AHP=28.59\%}$, $W_{FAHP=28\%}$) and consider it in the first option, also consultants support this option and recommend it as second option with percentage ($W_{AHP=23.34\%}$, $W_{FAHP=23.28\%}$). However, retrofit of building management systems in existing religious buildings was recommended only by owners as the most appropriate DSM option with percentage ($W_{AHP=15.45\%}$, $W_{FAHP=14.17\%}$).

The analysis of the pairwise judgments of academics, consultants, contractors and owners regarding the selection of the optimal DSM in religion buildings is considerably robust, as it was found to have an inconsistency ratio of less than 0.1.

It is to be noted that the results obtained using AHP and FAHP are highly consistent. The only exception was observed in the case of contractors, who according to AHP favour high efficiency lighting over high efficiency air conditioning while according to FAHP, favour high efficiency air conditioning over high efficiency lighting.

6.9 Analysis of the results for new religious buildings

In this section, a graphical comparison between weights of AHP and FAHP will be presented for both criteria and DSM alternatives of new religious building where the results from all groups of expert will be introduced and discussed.

6.9.1 Comparison of the results obtained for the criteria for new religious buildings

Figures in this section represent AHP and FAHP relative weights results of DSM criteria for new religious buildings for all groups of experts who participated in the questionnaire of this research phase.

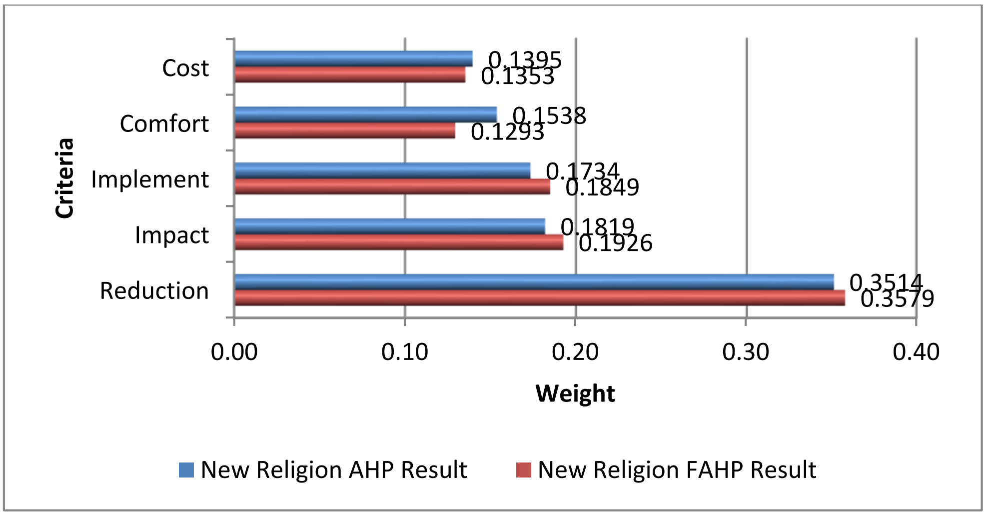


Figure 6.59 Opinion of academics on criteria of new religious buildings using AHP and FAHP

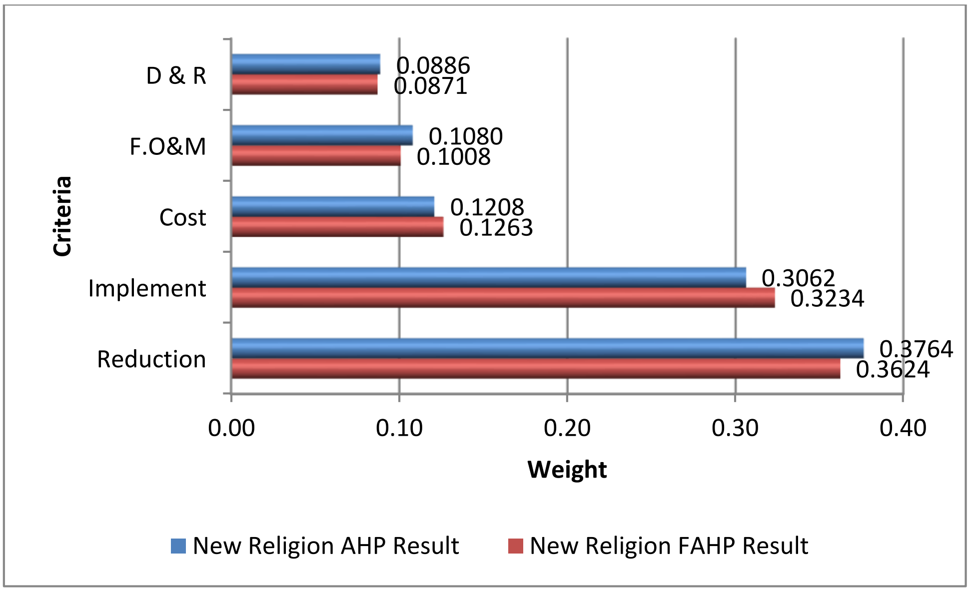


Figure 6.60 Opinion of consultants on criteria of new religious buildings using AHP and FAHP

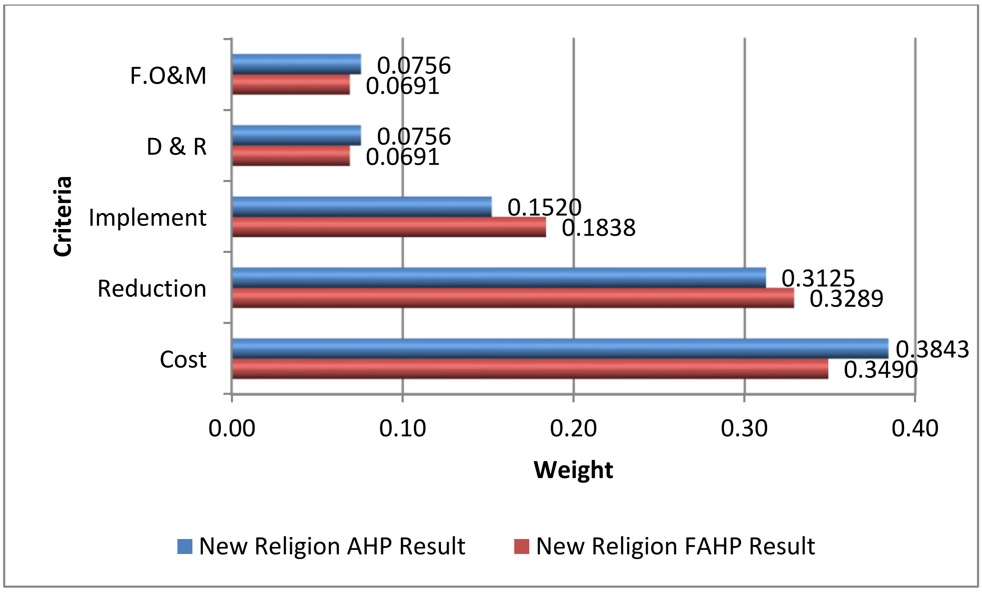


Figure 6.61 Opinion of contractors on criteria of new religious buildings using AHP and FAHP

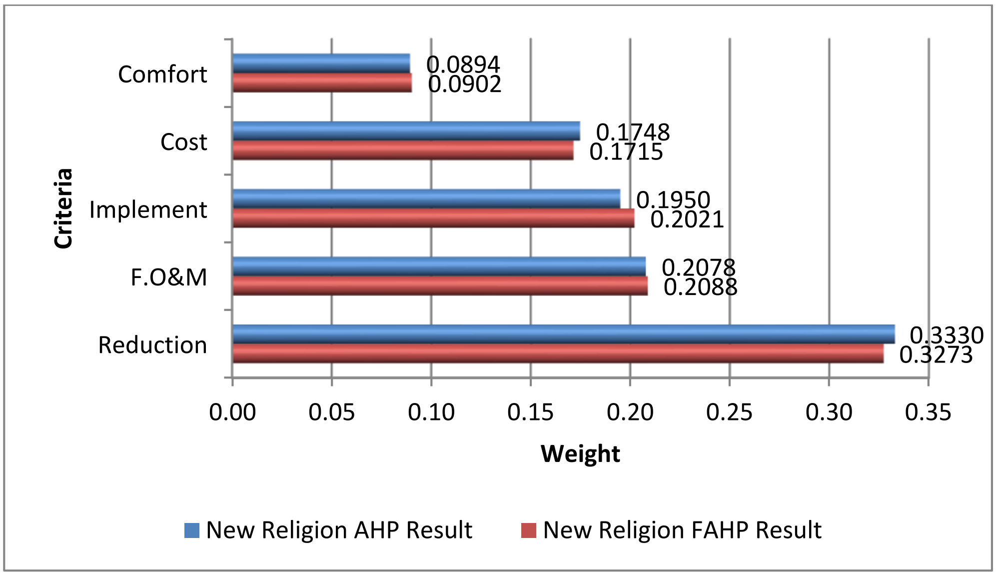


Figure 6.62 Opinion of owners on criteria for new religious buildings using AHP and FAHP

Figure 6.59 shows that the first three criteria have been ranked by both AHP and FAHP methods while the fourth and fifth positions are different for AHP and FAHP. For example, comfort criterion was the fourth according to AHP, whereas according to FAHP, it is ranked fifth. The exchange in priorities was with the cost criterion. Also in

Figure 6.62 there are some differences in the ranks, as ease of implementation criterion was the second in AHP, whereas in FAHP, it is ranked third. The exchange in priorities was with flexibility of operation and maintenance.

Figure 6.59 – Figure 6.62 show that most of the experts in all groups agree that reduction in consumption is the recommended criteria for the selection of DSM alternatives in new religious buildings. Academics, consultants and owners give it the highest weights of ($W_{AHP=35.14\%}$, $W_{FAHP=35.79\%}$), ($W_{AHP=37.64\%}$, $W_{FAHP=36.24}$) and ($W_{AHP=33.3\%}$, $W_{FAHP=32.73\%}$) respectively and rank it as the top criterion, while contractors rank it in second level with a percentage weight of ($W_{AHP=31.25\%}$, $W_{FAHP=32.89\%}$). This can be motivated by the same factors as explained earlier in this chapter.

Cost criterion was recommended by contractors as the most important criteria with a percentage weight of ($W_{AHP=38.43\%}$, $W_{FAHP=34.9\%}$), while academics rank it in the fourth level with a relatively low percentage weight of ($W_{AHP=13.95\%}$, $W_{FAHP=13.53\%}$) and consultants consider it in the third level with a similar percentage weight of ($W_{AHP=12.08\%}$, $W_{FAHP=12.63\%}$). Capital spending including installation expenditure requirements evaluation addresses the financial feasibility of the DSM options that are generally expected to be considered in the DSM selection process.

Ease of implementation criteria is recommended by all experts group. Academics, contractors and owners consider it in the third level with percentage weights of ($W_{AHP=17.34\%}$, $W_{FAHP=18.49\%}$), ($W_{AHP=15.20\%}$, $W_{FAHP=18.38\%}$), and ($W_{AHP=19.5\%}$, $W_{FAHP=20.21\%}$) respectively while consultants consider it in the second level with a percentage weight of ($W_{AHP=30.62\%}$, $W_{FAHP=32.34\%}$).

Criterion of flexibility of operation and maintenance for the candidate DSM technology is recommended by consultants, contractors and owners with percentage weights of ($W_{AHP=10.8\%}$, $W_{FAHP=10.08\%}$), ($W_{AHP=7.56\%}$, $W_{FAHP=6.91\%}$), and ($W_{AHP=20.78\%}$, $W_{FAHP=20.88\%}$) respectively. This criteria is proposed due the importance of the simplicity of operation and maintenance of a DSM technology.

The least important criterion for academics and owners was comfort to users with weights of ($W_{AHP=15.38\%}$, $W_{FAHP=12.93\%}$) and ($W_{AHP=8.94\%}$, $W_{FAHP=9.02\ \%}$). On the other hand, the least important criterion for consultants and contractors was the durability and reliability of the DSM option with weights of ($W_{AHP=8.86\%}$, $W_{FAHP=8.71\%}$) and ($W_{AHP=7.56\%}$, $W_{FAHP=6.91\%}$).

It is to be noted that the opinions of the experts in all the four groups regarding the criteria for selecting a DSM alternative remained the same as their opinions in the earlier case of existing buildings that are used for religious purposes.

6.9.2 Analysis of the results for DSM alternatives for new religious buildings

Figures in this section represent AHP and FAHP relative weights results of DSM alternatives for new religious buildings for all groups of experts who participated in the questionnaire of this research phase.

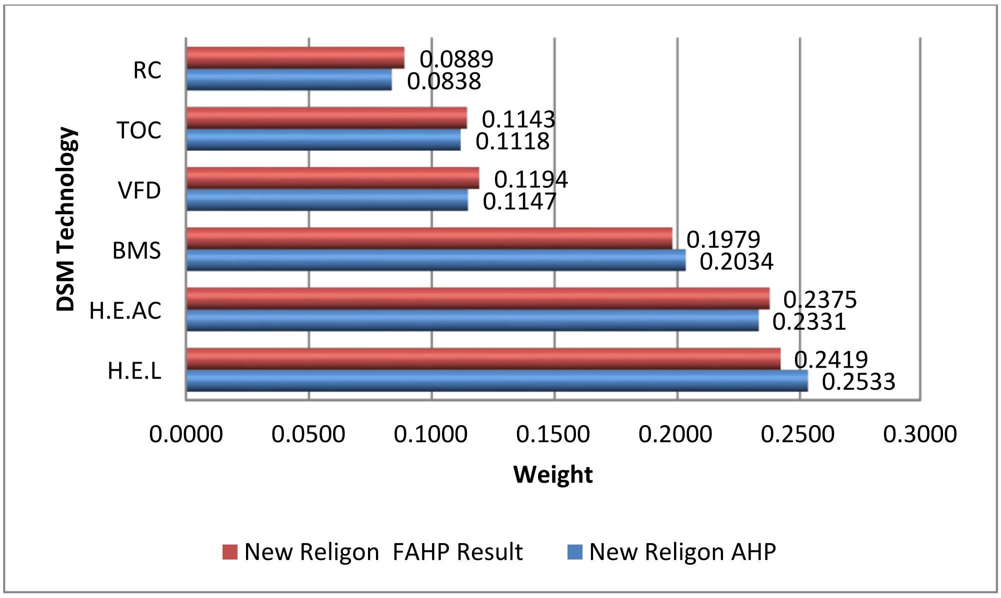


Figure 6.63 Opinion of academics on the DSM alternatives for new religious buildings using AHP and FAHP

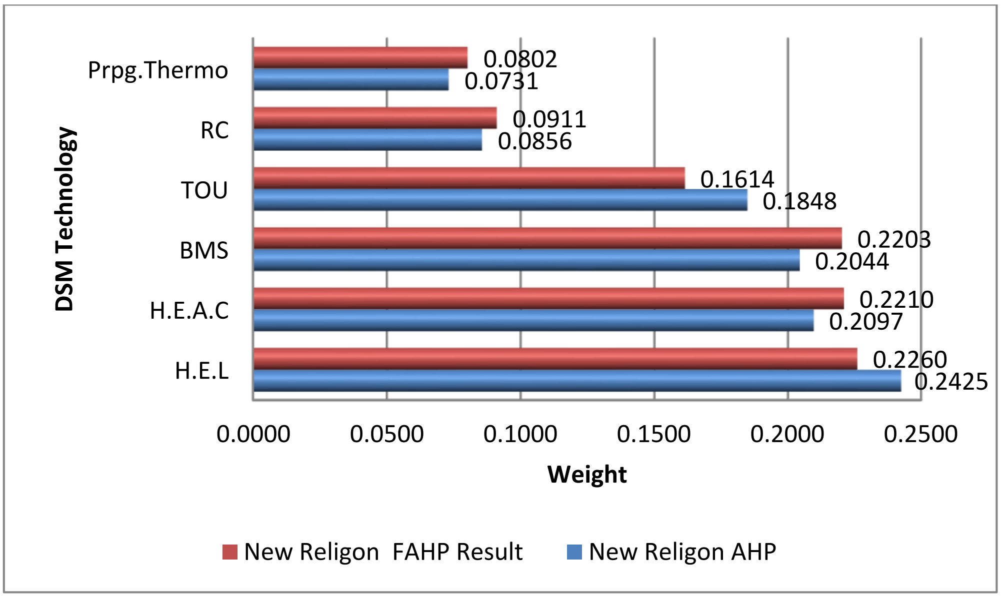


Figure 6.64 Opinion of consultants on the DSM alternatives for new religious buildings using AHP and FAHP

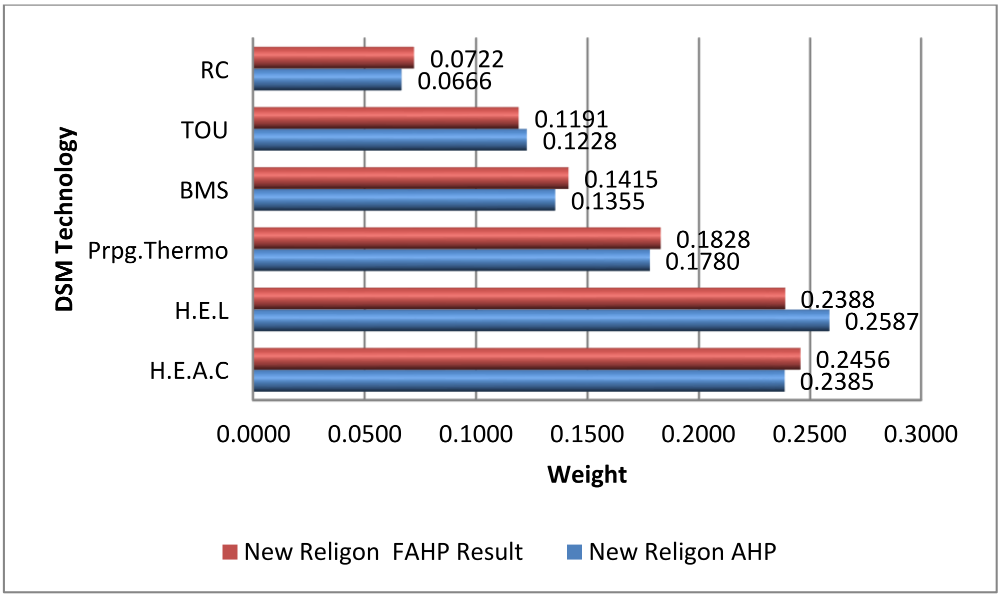


Figure 6.65 Opinion of contractors on the DSM alternatives for new religious buildings using AHP and FAHP

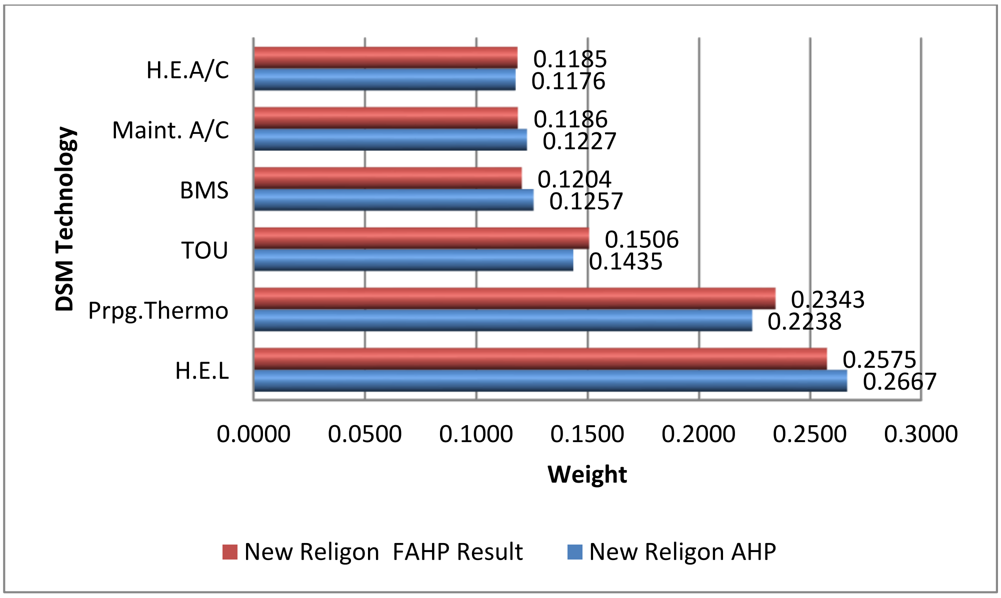


Figure 6.66 Opinion of owners on the DSM alternatives for new religious buildings using AHP and FAHP

Figure 6.63 – Figure 6.66 show that high efficiency lighting was regarded by the academic, consultant, contractor and owner experts as being the most recommended DSM option for new religious buildings, followed by high efficiency air conditioning systems except the owners who rank this option as the fifth recommended option.

Building management system was also recommended by academics and consultants as the third option while contractors and owners consider it as the fifth option. The academic experts ranked variable frequency drives, time of use control for lighting and remote control for air conditioning as the lowest recommended options. The analysis of the pairwise judgments of academic group regarding the selection of the optimal DSM in new religious buildings is considerably robust, as it was found to have an inconsistency ratio of less than 0.1.

All the groups of experts agreed that designing new religious buildings with high efficiency lighting can be considered as the most appropriate DSM option. Academics, consultants, contractors and owners consider it as the first option with percentage weights of (W_{AHP}=25.33%, W_{FAHP}=24.19%), (W_{AHP}=24.25%, W_{FAHP}=22.6%), (W_{AHP}=25.87%, W_{FAHP}=23.88%), and (W_{AHP}=26.67%, W_{FAHP}=25.75%) respectively. A possible reason for such an assignment of ranks could be that installing new efficient equipment in new buildings is expected to be a more cost-effective approach compared to the installation of low efficiency ones. This justification is also supported by the opinion of all the experts about installing high efficiency A/C systems in new religious buildings. This option is regarded by the academic, consultant, and contractor experts as the second recommended DSM option for new religious buildings with percentage weights of ($W_{AHP=23.31\%}$, $W_{FAHP=23.75\%}$), ($W_{AHP=20.97\%}$, $W_{FAHP=22.10\%}$), and ($W_{AHP=23.85\%}$, $W_{FAHP=24.56\%}$), while owners consider in the fifth DSM option with a percentage weight of ($W_{AHP=12.27\%}$, $W_{FAHP=11.86\%}$).

Building management system is recommended by academics and consultants as the third option with percentage weights of ($W_{AHP=20.34\%}$, $W_{FAHP=24.19\%}$) and ($W_{AHP=20.44\%}$, $W_{FAHP=22.03\%}$) and fourth option by contractor and owner groups with percentage weights of ($W_{AHP=14.15\%}$, $W_{FAHP=13.55\%}$) and ($W_{AHP=12.57\%}$, $W_{FAHP=12.04\%}$) respectively.

Most of the experts in academic, consultant and contractor groups feel that remote control for air conditioning option is not highly recommended for new religious buildings where they give the following respective weights to this option: ($W_{AHP=8.38\%}$, $W_{FAHP=8.89\%}$), ($W_{AHP=8.56\%}$, $W_{FAHP=9.11\%}$), and ($W_{AHP=6.66\%}$, $W_{FAHP=7.22\%}$), while owners do not consider it as one of the most six recommended DSM options for new religious buildings.

Maintenance of air conditioning was recommended by owners group only while academics recommend installation of variable frequency drives for air conditioning systems.

The analysis of the pairwise judgments of academic, contractor and owner groups regarding the selection of the optimal DSM in new religious buildings is considerably robust, as it was found to have an inconsistency ratio of less than 0.1.

It is worth mentioning that the rank and weight of these criteria differed from one group to other based on various buildings types. Moreover, impact on environment criterion was only recommended by academics. Having said that, overall, it can be concluded that reduction in consumption, ease of implementation and cost were of common interest to almost all the groups. It is understandable since for the adoption of any technology, it is desirable that the technology is cost-effective, it is simple to use, understand and implement, and that it can be used cheaply for a long duration. It is good to see that experts from different groups acknowledge these important aspects of technology. The adoption of a DSM based on these criteria (especially reduction in consumption) will also help the government to better manage its power resources and will help in improving the environment as excessive consumptions can become a threat to it.

6.10 Summary of the results

The ranks of all the criteria and Demand Side Management (DSM) alternatives for all types of buildings based on the judgments of all groups of experts are summarized in Table 6.4 and Table 6.5 respectively.

Table 6.4 The final rank of the criteria using AHP/FAHP technique

Building type	Criteria rank	Academics Group AHP	Academics Group FAHP	Consultants Group AHP	Consultants Group FAHP	Contractors Group AHP	Contractors Group FAHP	Owners Group AHP	Owners Group FAHP
Existing Office	1	Reduction	Reduction	Reduction	Reduction	Cost	Cost	Cost	Cost
	2	Implement	Implement	Implement	Implement	Reduction	Reduction	Reduction	Reduction
	3	Impact	Impact	Cost	Cost	Implement	Implement	F.O&M	F.O&M
	4	Cost	Cost	F.O&M	F.O&M	F.O&M	F.O&M	Implement	Implement
	5	Comfort	Comfort	D & R	D & R	D & R	D & R	Comfort	Comfort
New Office	1	Reduction	Reduction	Reduction	Reduction	Cost	Cost	Cost	Cost
	2	Implement	Implement	Implement	Implement	Reduction	Reduction	Implement	Implement
	3	Impact	Impact	Cost	Cost	Implement	Implement	Reduction	Reduction
	4	Cost	Cost	F.O&M	F.O&M	F.O&M	F.O&M	F.O&M	F.O&M
	5	Comfort	Comfort	D & R	D & R	D & R	D & R	Comfort	Comfort
Existing School	1	Reduction	Reduction	Reduction	Reduction	Cost	Cost	Cost	Cost
	2	Implement	Implement	Implement	Implement	Reduction	Reduction	Reduction	Reduction
	3	Cost	Cost	Cost	Cost	Implement	Implement	F.O&M	F.O&M
	4	Comfort	Comfort	F.O&M	F.O&M	D & R	D & R	Implement	Implement
	5	Impact	Impact	D & R	D & R	F.O&M	F.O&M	Comfort	Comfort
New School	1	Reduction	Reduction	Reduction	Reduction	Cost	Cost	Cost	Cost
	2	Implement	Implement	Implement	Implement	Reduction	Reduction	Reduction	Reduction
	3	Cost	Cost	Cost	Cost	Implement	Implement	F.O&M	F.O&M
	4	**<u>Comfort</u>**	**<u>Impact</u>**	F.O&M	F.O&M	D & R	D & R	Implement	Implement
	5	**<u>Impact</u>**	**<u>Comfort</u>**	D & R	D & R	F.O&M	F.O&M	Comfort	Comfort
Existing Religion	1	Reduction	Reduction	Reduction	Reduction	Cost	Cost	Reduction	Reduction
	2	Impact	Impact	Implement	Implement	Reduction	Reduction	**<u>Implement</u>**	**<u>F.O&M</u>**
	3	Implement	Implement	Cost	Cost	Implement	Implement	**<u>F.O&M</u>**	**<u>Implement</u>**
	4	**<u>Comfort</u>**	**<u>Cost</u>**	F.O&M	F.O&M	D & R	D & R	D & R	D & R
	5	**<u>Cost</u>**	**<u>Comfort</u>**	D & R	D & R	F.O&M	F.O&M	Comfort	Comfort
New Religion	1	Reduction	Reduction	Reduction	Reduction	Cost	Cost	Reduction	Reduction
	2	Impact	Impact	Implement	Implement	Reduction	Reduction	**<u>Implement</u>**	**<u>F.O&M</u>**
	3	Implement	Implement	Cost	Cost	Implement	Implement	**<u>F.O&M</u>**	**<u>Implement</u>**
	4	**<u>Comfort</u>**	**<u>Cost</u>**	F.O&M	F.O&M	D & R	D & R	D & R	D & R
	5	**<u>Cost</u>**	**<u>Comfort</u>**	D & R	D & R	F.O&M	F.O&M	Comfort	Comfort

The items in bold and underlined format represent the change in rank between AHP and FAHP.
Impact: Impact on environment , **Implement**: Ease of Implementation , **Comfort**: Comfort to users
Cost: Capital cost , **Reduction:** Reduction in consumption , **F.O&M:** Flexibility of operations and maintenance , **D&R:** Durability and reliability

Table 6.5 The final rank of the DSM alternatives using AHP/FAHP technique.

Building type	Alternative rank	Academics Group AHP	Academics Group FAHP	Consultants Group AHP	Consultants Group FAHP	Contractors Group AHP	Contractors Group FAHP	Owners Group AHP	Owners Group FAHP
Existing Office	1	**BMS**	**PGT**	PGT	PGT	**H.E.L**	**H.E.A.C**	H.E.L	H.E.L
	2	**PGT**	**BMS**	TOU	TOU	**H.E.A.C**	**H.E.L**	PGT	PGT
	3	H.E.L	H.E.L	BMS	BMS	PGT	PGT	**BMS**	**H.E.A.C**
	4	TOU	TOU	RC	RC	TOU	TOU	**H.E.A.C**	**BMS**
	5	RC	RC	H.E.L	H.E.L	BMS	BMS	Maint. A/C	Maint. A/C
	6	P.F	P.F	H.E.A.C	H.E.A.C	RC	RC	P.F	P.F
New Office	1	H.E.A.C	H.E.A.C	H.E.A.C	H.E.A.C	PGT	PGT	H.E.L	H.E.L
	2	BMS	BMS	PGT	PGT	**H.E.L**	**H.E.A.C**	PGT	PGT
	3	H.E.L	H.E.L	H.E.L	H.E.L	**H.E.A.C**	**H.E.L**	H.E.A.C	H.E.A.C
	4	PGT	PGT	BMS	BMS	BMS	BMS	P.F	P.F
	5	RC	RC	TES	TES	RC	RC	BMS	BMS
	6	TES	TES	RC	RC	TES	TES	TES	TES
Existing School	1	PGT	PGT	H.E.A.C	H.E.A.C	**H.E.L**	**H.E.A.C**	H.E.L	H.E.L
	2	H.E.L	H.E.L	PGT	PGT	**H.E.A.C**	**H.E.L**	PGT	PGT
	3	VFD	VFD	Maint. A/C	Maint. A/C	TOU	TOU	TOU	TOU
	4	TOU	TOU	RC	RC	PGT	PGT	VFD	VFD
	5	**P.F**	**RC**	H.E.L	H.E.L	Maint. A/C	Maint. A/C	RC	RC
	6	**RC**	**P.F**	TOU	TOU	RC	RC	P.F	P.F
New School	1	H.E.L	H.E.L	**H.E.A.C**	**T.E.S**	PGT	PGT	H.E.L	H.E.L
	2	H.E.A.C	H.E.A.C	**T.E.S**	**H.E.L**	H.E.L	H.E.L	PGT	PGT
	3	BMS	BMS	**H.E.L**	**H.E.A.C**	H.E.A.C	H.E.A.C	H.E.A.C	H.E.A.C
	4	PGT	PGT	RC	RC	BMS	BMS	TOU	TOU
	5	VFD	VFD	BMS	BMS	RC	RC	BMS	BMS
	6	RC	RC	PGT	PGT	T.E.S	T.E.S	TES	TES
Existing Religion	1	PGT	PGT	PGT	PGT	**H.E.L**	**H.E.A.C**	H.E.L	H.E.L
	2	H.E.L	H.E.L	H.E.A.C	H.E.A.C	**H.E.A.C**	**H.E.L**	PGT	PGT
	3	P.F	P.F	P.F	P.F	PGT	PGT	BMS	BMS
	4	TOU	TOU	H.E.L	H.E.L	TOU	TOU	Maint. A/C	Maint. A/C
	5	RC	RC	TOU	TOU	P.F	P.F	TOU	TOU
	6	VFD	VFD	R.C	RC	RC	RC	P.F	P.F
New Religion	1	H.E.L	H.E.L	H.E.L	H.E.L	H.E.A.C	H.E.A.C	H.E.L	H.E.L
	2	H.E.A.C	H.E.A.C	H.E.A.C	H.E.A.C	H.E.L	H.E.L	PGT	PGT
	3	BMS	BMS	BMS	BMS	PGT	PGT	TOU	TOU
	4	VFD	VFD	TOU	TOU	BMS	BMS	BMS	BMS
	5	TOU	TOU	RC	RC	TOU	TOU	Maint. A/C	Maint. A/C
	6	RC	RC	PGT	PGT	RC	RC	H.E.A.C	H.E.A.C

The items in bold and underlined format represent the change in rank between AHP and FAHP.

H.E.L: High efficiency lighting **PGT:** Programmable thermostat , **P.F:** Power factor correction
H.E.A.C: High efficiency air conditioning , **BMS:** Building management system, **TOU:** Time of Use
Maint. A/C: Maintenance of air conditioners, **VFD:** Variable frequency drives, **R.C:** Remote control for air conditioning

Table 6.6 The two most recommended DSM options by experts in all the groups.

Building type	Academics Group	Consultants Group	Contractors Group	Owners Group
Existing Office	BMS	PGT	H.E.L	H.E.L
	PGT	TOU	H.E.A.C	PGT
New Office	H.E.A.C	H.E.A.C	PGT	H.E.L
	BMS	PGT	H.E.L/H.E.A.C	PGT
Existing School	PGT	H.E.A.C	H.E.L	H.E.L
	H.E.L	PGT	H.E.A.C	PGT
New School	H.E.L	T.E.S	PGT	H.E.L
	H.E.A.C	H.E.L/H.E.A.C	H.E.L	PGT
Existing Religious	PGT	PGT	H.E.L	H.E.L
	H.E.L	H.E.A.C	H.E.A.C	PGT
New Religious	H.E.L	H.E.L	H.E.A.C	H.E.L
	H.E.AC	H.E.AC	H.E.L	PGT

6.11 Discussion

A number of key findings have emerged from the results presented in Section 6.4 – Section 6.9. This section will discuss their implications for DSM in Kuwait and more widely.

6.11.1 Identification of criteria

With regards to identifying important criteria for selecting an appropriate DSM technology for each type of building, reduction in consumption, ease of implementation, and capital cost were the most commonly favoured criteria. Among these, reduction in consumption and ease of implementation are two criteria which are recommended for all types of buildings by all the experts. One reason for the agreement of all the experts on reduction of consumption being an important criteria in the selection of a DSM technology could be that the experts are of the opinion that the main purpose of a DSM technology is to reduce consumption. On the other hand, cost is recommended for all types of buildings by the academics, contractors and consultants. The owners also agree on this with the exception of owners of religious buildings. The disregard for cost criteria for religious buildings could possibly be attributed to the sentimental attachment of the owner experts with religious buildings due to which they seem to be of the opinion that that higher cost should not be a hindrance in the installation of the right DSM technology in religious buildings. Another reason for the disregard for cost criteria for religious buildings could be that most of the experts in the owners group belong to the Ministry of Islamic Affairs which has a huge annual budgetary allocation from the Kuwait government and hence they might be of the opinion that for a suitable DSM technology, cost would never be a problem for them. Moreover, academics never recommend durability & reliability and flexibility of operations & maintenance for any type of building. A possible motivation behind this could be that a compromise on durability and reliability could have consequences for the reputation of consultants and contractors and a financial impact on the owners while it does not appear to have any direct consequences for academics. Another reason for this could be the practical consequences of a compromise on durability & reliability and flexibility of operations & maintenance for the owners, consultants, and contractors. Hence, the experts from these three groups want reliable buildings with low maintenance cost. Durability and reliability is not favoured by owners for office and school buildings (new and existing) as well. It is possible that the lack of practical experience of the owners and academics (who also do not consider it important) compared to consultants and contractors, who are expected to be more aware of the practical side of the implementation of DSM technologies, is a reason they do not consider it important. Similarly, comfort is never recommended by contractors and consultants for any type of building. Impact on environment is included by academics for all building types, though never with high priority, but in contrast never recommended by contractors, consultants and owners for any type of building. This may be because academics are more aware of the impact of high energy use and carbon emissions on the environment. It may also mean that the non-academic experts might think that reduction in consumption will also lower the impact on the environment, so do not feel the need to consider impact on environment independently.

- **For existing and new buildings**

  The experts seem to have largely similar opinions about important criteria for both existing and new buildings. The only exception is in the criteria ranking for office buildings by the owners. For existing buildings they consider (in order of decreasing importance) reduction in consumption, F.O&M, and ease of implementation, while for new buildings they consider ease of implementation to be more important than reduction in consumption which in turn is deemed more important than F.O&M. One reason for which the experts consider reduction in consumption less important in new buildings compared to existing buildings could be that they assume new buildings will be efficient anyway. The case of ease of implementation is very interesting as it is deemed the least important of the above three criteria for existing buildings and most important of them for new buildings. This possibly suggests that for existing buildings, the experts are willing to put extra effort in the implementation of a DSM technology if it can promise a reduction in consumption. An easy to implement DSM technology may also motivate the architects of the new buildings to consider the DSM technology during the design of the new buildings. On the other hand, a compromise on ease of implementation for new buildings can affect cost, build time and ease of build etc.

- **For office, school, and religious buildings**

  The experts seem to have a similar opinions about the important criteria for office and school buildings. Their opinion about religious buildings is slightly different with respect to the other two types of buildings. This is reflected in their assignment of ranks. For example, all the experts agree that reduction in consumption, ease of implementation and cost are the three most important criteria for school and office buildings, while for religious buildings, cost is not considered as an important criteria by the owners. The disregard for cost criteria for religious buildings could possibly be attributed to the sentimental attachment of the owner experts with religious buildings due to which they seem to be of the opinion that that higher cost should not be a hindrance in the installation of the right DSM technology in religious buildings

6.11.2 Identification of DSM technology

With regards to the identification of DSM technologies for governmental buildings in Kuwait, high efficiency lighting and programmable thermostats were the most commonly recommended DSM technologies. Among these, high efficiency lighting is unanimously recommended by all the experts for all types of buildings. A possible reason for this could be that generally, high efficiency lighting has a low cost associated with it and is easily implementable. As cost and ease of implementation are among the top criteria for the selection of DSM technologies, high efficiency lighting seems to be an obvious choice. On the other hand, programmable thermostats were recommended by all the experts for all types of buildings except for new religious buildings by academics. High efficiency air conditioning and remote controls are jointly recommended as the third important DSM technology. As air-conditioning is generally responsible for very high energy consumption, it is understandable that the experts deem it important to install high efficiency air conditioning which could make it possible to reduce the energy consumption. On the other hand, variable frequency drives and maintenance of air conditioning are jointly recommended as the least important DSM technologies. One reason for such a low preference for variable frequency drives could be that perhaps some groups don’t know much about them.

- **For existing and new buildings**

Some interesting observations can be made about the choices of experts for existing and new buildings. For example, for existing buildings, only high efficiency lighting and programmable thermostats are unanimously recommended. On the other hand, for new buildings, high efficiency lighting, high efficiency air conditioning and building management system are all unanimously recommended. It is interesting to note that while the academics consider programmable thermostats important for all types of existing buildings; among new buildings, they don't consider it important for religious buildings. This is in sharp contrast to their opinion about programmable thermostats in new religious buildings as they consider it the best DSM technology for these buildings. One reason for this could be that they assume such controls will be already implemented in these buildings. Similarly, thermal energy storage is not recommended by any of the experts for any type of existing building. This possibly suggests that for existing buildings, the experts do not prefer the installation of a technology that cannot provide instant heating or cooling. Or possibly, this is because retrofit thermal energy storage in existing buildings is not practically easy and is expected to incur a substantial cost. On the other hand, thermal energy storage is considered an important technology by each of the expert groups for at least one of the new buildings.

- **For office, school, and religious buildings**

  High efficiency lighting was unanimously recommended as an important DSM technology by all the experts for all types of buildings. On the other hand, programmable thermostats were recommended by all the experts for office and school buildings. Similarly, building management systems were recommended by all the experts for office buildings while time of use control for lighting was recommended by all the experts for religious buildings. It is possible that the choice of time of use lighting for religious buildings is motivated by the nature of occupancy of these buildings which is generally more intermittent compared to office and school buildings. Another interesting observation is that variable frequency drives were not recommended by any of the experts for office buildings. Similarly, thermal energy storage systems were not recommended by any of the experts for religious buildings. Again, it is possible that the experts do not find thermal energy storage systems to be an efficient choice for places with intermittent occupancy such as religious buildings or perhaps they are not familiar with thermal energy storages systems and their potential benefits.

6.11.3 Practical contributions to knowledge

The results obtained in this research could be significant for both DSM assessment and the energy management industries in Kuwait by:

- Providing a general overview of the influence of criteria and factors associated with the selection of DSM alternatives in governmental buildings and their effects on the decision-making process.
- Providing a better understanding of decision making processes for energy management by taking into account the practical point of view as well as other traditional evaluation methods.
- Introducing a set of structured techniques to decision makers in energy management field based on expert consensus.
- Identifying a model for improvement in the decision making process to overcome the limitation in decision making practices in energy management industry.
- Providing the decision makers in building energy management five criteria and six DSM options which are important in the selection and evaluation of each type of governmental building (i.e., existing and new office, school, and religious buildings).

The research also provides an opportunity for the Kuwaiti government to get an insight into the most promising DSM technologies for different types of buildings in Kuwait. This is a unique opportunity as the DSM technologies identified in this research have been recommended by a number of experts from a variety of technical and professional backgrounds. This knowledge can be helpful for any future pilot projects on DSM measures in Kuwait government buildings and in the development of policy, legislation and buildings codes etc.

6.11.3.1 Cost and time implications of adopting the proposed framework

Unlike engineering approaches which sometimes depend on expensive test equipment or, often for building design, expensive computer modelling exercises, the proposed framework can be easily adopted by anyone without any significant financial cost.

As for time, some challenging and time consuming aspects of the proposed framework, which emerged from the research, include: the identification of a variety of experts and stakeholders from different professional backgrounds, designing the questionnaires required for data gathering, analysing the obtained data. The time required for each of these aspects will depend on various factors: e.g., the size of the project, the number of experts, and the availability of the experts, to name a few. Similarly, the Delphi method uses an iterative approach to reach to a consensus among the experts. This can also be a time consuming process but the amount of time spent during this process is difficult to predict as it depends on the responses of the participating experts and the facilitator conducting the study. Hence, for small projects adopting the proposed framework might not be feasible. But for large projects, involving many buildings, there are various potential benefits of adopting this approach (e.g., economic, environmental etc.) which can justify the time spent in adopting the proposed framework.

6.11.4 Implications of the results for the Kuwaiti government

The results can be used by the Kuwaiti government to implement appropriate DSM technologies in its existing and new office, school and religious buildings. For example, high efficiency lighting has been unanimously recommended for all types of buildings. Lighting systems account for 20% of the peak power demand and 15% of the annual energy consumption in Kuwait government buildings (Al-Naqib et al., 2010). Hence, by installing high efficiency lighting in Kuwaiti governmental buildings, the Kuwaiti government can expect to reduce both the peak power demand and annual energy consumption. Similarly, programmable thermostats are recommended to be installed in all office and school buildings by all the experts. Cooling of buildings account for around 70% of the annual peak power demand and 40% of the annual energy consumption in Kuwait (Maheshwari et al., 2001b). With the use of programmable thermostats for air conditioners, energy savings of 46% and 25% can be achieved for school and office buildings in Kuwait (Maheshwari, 2001b). This will have financial as well as environmental benefits. For religious buildings, installing building management systems have been recommended by all experts. With the help of a building management system, the energy consumption of a building can be reduced by up to half (Kamali et al., 2014). Hence, installing them in Kuwaiti religious buildings, the government can expect to reduce the load on power generation facilities while reducing the energy bills and carbon emissions at the same time.

6.11.5 Implications of the results for other developing countries

The author believes that the results obtained during this research could be used directly in similar countries (with respect to climate, building stock etc.) in the Middle East region or at least serve as a starting point, with a caveat that they could be less reliable than in Kuwait.

For other developing countries in other regions, while certain aspects of this research can be helpful, the results of this research cannot be directly adopted in those countries. This is because the results in this research were based on the judgements of experts, who on the one hand came from a variety of professional backgrounds but were representative of Kuwaiti population. Their judgements might have been influenced by the socio-economic conditions, culture, personal preferences, living style, level of access to technology, and most importantly by the climate in Kuwait. These factors might not be the same in other developing countries, especially those that are out of the Middle East. Hence, this research does not identify the most suitable DSM technologies for these countries but it provides a framework which people in these countries can adopt in order to choose an appropriate DSM technology for their buildings.

6.11.6 AHP vs. FAHP

Compared to AHP, FAHP was employed to consider the fuzziness of the decision makers. The crisp data used in the AHP approach was transferred to FAHP approach and the findings were illustrated. AHP method can easily incorporate fuzzy data as well as assist in group decision making.

Results for both the AHP and FAHP methods are discussed in Section 6.3 – Section 6.9 and summarized in Section 6.10. An interesting observation is that while there were minor difference between the results obtained using AHP and FAHP for both criteria and DSM technologies, the ranking yielded from both the approaches are practically identical in most cases. This finding supports the idea of Saaty (2008) since he is against fuzzifying the AHP. Saaty argues that fuzzification of the AHP process does not give much difference in results since the AHP, from his point view, is already a fuzzy process because most ratios of ranking are not crisp numbers. On the other hand some researchers believe that AHP and FAHP complement each other for example Ayag (2005) and Kwong and Bai (2002). Ozdagoglu and Ozdagoglu (2007) conclude that many decisions in complex business situations are made in an environment of uncertainty, which benefits from the utilization of fuzzy AHP. However, crisp and fuzzy AHPs do not oppose but complement each other since the degree of uncertainty determines the use of the particular method.

For the case in this research, results obtained using AHP are closely similar to those obtained using FAHP which suggests that the use of FAHP was not particularly beneficial. So, it can be concluded that using AHP is sufficient for this kind of buildings efficiency problem.

6.11.7 Methodological contributions

Engineering approaches for decision making and obtaining results mostly focus on simulation, modelling and optimization based on scientific theories as well as on software, while this study introduces a novel approach in decision making which is based on the multi criteria decision making using AHP and FAHP methods. The research proposed a decision making model that could satisfy the needs of decision makers in order to solve the problem around the selection of DSM alternatives in buildings. While it opens many new directions for research, the results obtained during this research give credence to the argument that AHP alone is, sometimes, sufficient and that at least in the case of this study, FAHP was not found to be beneficial, in that it gave almost identical results to AHP. Hence, precious time can be saved by focusing only on AHP in other similar studies in the future.

Moreover, the AHP-Delphi decision model, based on a systematic group decision approach, used in this research to screen and prioritize the optimal criteria and DSM technologies can be used for other decision problems which consider multiple criteria.

Chapter 7. *CONCLUSIONS AND RECOMMENDATIONS*

7.1 Introduction

This thesis aimed to establish a systematic method for the assessment and evaluation of DSMs in Kuwaiti governmental buildings. For this purpose, a multicriteria decision model, based on AHP and Delphi techniques, was proposed. To meet this aim, the overall project was divided into five objectives.

The first objective of the thesis was to identify potentially viable DSM alternatives and criteria which can be considered in the selection and evaluation processes of governmental buildings. A literature review was conducted for this purpose. Moreover, a variety of experts were approached and their opinions regarding viable DSM alternatives and important criteria for their selection were obtained with the help of questionnaires. Some important criteria that were identified, among others, were: flexibility for operation & maintenance, durability and reliability, capital cost, reduction in consumption, comfortability for users, impact on environment (reduction of GHG emissions), payback period, technology life cycle, ease of implementation, after sale service, and the availability of the technology. Similarly important DSM technologies were also identified. These included among others, programmable thermostats, high efficiency A/C units, variable frequency drives, and high efficiency lighting.

The second and third objectives of the research objective were to screen the respective lists of potentially important criteria and DSM technologies that were identified in the previous stage. For this purpose, Delphi process was used to screen out the less important criteria and technologies.

The fourth research objective was to design a model based on AHP which could analyse DSM alternatives and to use this model to identify the optimal DSM alternative for government buildings. For this purpose, a model was developed as an Excel worksheet. It was validated by comparing its results with those of three other published works: Charania *et al.* (2001), Vashishthaa and Ramachandranb (2006), and Metty and Beckwith (2002). The model provided decision makers with a systematic, clear and structured framework that could improve the decision making process. All criteria and DSM alternatives were carefully considered to ensure that rational judgment is made in the selection of important DSM options for each type of government building considered in this research. Important criteria identified included reduction in consumption, ease of implementation, and capital cost.

The last objective of the research was to employ FAHP in the model developed in the previous stage and assess its effect on the results compared to the AHP based model. It was found that AHP, alone, was sufficient for the selection of DSM technologies in government buildings. It would seem reasonable to conclude that this would hold true for most building types.

7.2 Main Contributions

As discussed in Section 6.11, the thesis has made a contribution to knowledge in a number of areas including practice (both inside and outside Kuwait), method (critiquing, testing and integrating AHP and Delphi), and theory (generic insight about DSM). These can be summarized as follows:

- It developed a multi criteria decision model for the selection of optimal DSM measures in buildings. The model uses Delphi process to screen out less desirable criteria and DSM technologies while it uses AHP for prioritizing the remaining important criteria and DSM technologies. The model is flexible and generic and can be used by anyone to select optimal DSM measures in buildings. Moreover, it can be adapted to solve other multi criteria decision problems as well.
- It identified important criteria for the selection of DSM technologies in both existing and new office, school and religious buildings in Kuwait. Reduction in consumption, ease of implementation, and capital cost were identified as some of the most important criteria. The identified criteria can be used to understand the priorities of different groups of experts with respect to the selection of DSM technologies in buildings.
- It identified important DSM technologies in both existing and new office, school and religious buildings in Kuwait. High efficiency lighting was recommended by all the experts for all types of buildings while programmable thermostats were recommended for office and school buildings, and building management

systems for religious buildings. The identified DSM technologies can be used to reduce both peak and annual power consumption in Kuwait which can be of both financial and environmental benefit to the Kuwaiti government.

- The use of a diverse set of stakeholders and experts such as academics, consultants, contractors, and owners helps identify issues which might not have been otherwise identified using conventional engineering approaches or by relying only on the expertise of engineering consultants or contractors. the research identified that due to the particular funding and cultural context of religious buildings, cost is not recognized as a constraint by the owners.
- It compares the performance of FAHP and AHP for the evaluation of DSM technologies and criteria for their installation in various government buildings and concludes that AHP alone is sufficient to address this kind of problem and fuzzifying it does not improve the results. Especially, for the identification of important criteria for the selection of DSM technologies, no difference was observed between the results obtained using AHP and FAHP for the contractor and consultant groups.

7.3 Limitations of the research

Apart from the contributions identified in the previous section, the thesis also has some limitations that are common in most in-depth case study investigations. These are:

- The generalization of the results is limited by the population used i.e., the results of this research reflected only the opinions of experts who participated in the three phases of this research.
- The research dealt with the problem of energy management in government buildings (offices, schools and religious buildings) in Kuwait, and surveyed the most important participants: academics, consultants, contractors and owners. The results may not be directly applicable to other types of buildings.
- The research was applied and tested in Kuwait only. So the generalization of the results in other countries may require a study of several factors related to these countries. For example, the climate, the building systems, the energy resources, and the availability of technology in those countries, to name a few. Countries in the Middle East region might be an exception to this where the results of this

study can be readily adopted. This is because many of these countries share similar climate, buildings systems, energy resources etc. as those of Kuwait.

- The data for this research was collected by one person. Hence, it is possible that researcher's bias might have influenced the results.

7.4 Recommendations for future research:

The findings of this research support the view that the decision making in energy management should be further researched in order to understand the perspective of this portion of the energy management industry. However, there are requirements to implement further research in order to understand decision making to a deeper extent in the building energy management assessments. Suggested areas of further research include, but are not limited to the following areas:

- The effect of using other fuzzy multi-criteria methods such as fuzzy outranking or fuzzy TOPSIS methods can be assessed and compared with the current methodology which uses AHP/FAHP. That is, after the Delphi stage, instead of using AHP/FAHP to quantify and rank the DSM technologies, fuzzy outranking or fuzzy TOPSIS may be employed for the same purpose. The results of these two approaches should then be analysed and compared with each other to identify their strengths and weaknesses.
- Sensitivity analysis is a tool that determines if the solution is implementable and robust (Saaty, 2013). For simplicity, the proposed model did not contain sensitivity analysis. In future research, the model may also be subjected to a detailed sensitivity analysis.
- The practical implementation and validation of the proposed decision making model in real case studies may be considered as it may change some dimensions of the framework and the process. Moreover, the proposed multicriteria decision model can be used as a trial framework in other similar studies involving different cultural, sectorial contexts.
- The study does not currently include the impact of the results in a real case study of governmental buildings in Kuwait. The application of the DSM with

subsequent monitoring of its effects on energy use and peak load would be beneficial.

- Decomposing the general evaluation criteria into smaller sub-criteria will improve the evaluation process. The research criteria model may not be sufficient alone without sub-criteria. Moreover, there are some sub-criteria, which can be improved or added for the better model performance.
- This research was based on governmental buildings, so further research can be carried out on other building types such as: residential, commercial and industrial buildings.
- Pre-screening for the proposed DSM options could be applied through an economic analysis such as cost-benefit analysis. This will improve the feasibility of the proposed DSM option and enhance the evaluation process in future research.
- The MS Excel program for Fuzzy AHP could be developed and combined with the current MS Excel program for AHP which is created in this research in order to make the application of these techniques easier.
- The area of research can be expanded to investigate other countries besides Kuwait, also to extract some valuable international comparisons.
- Further research is required to identify state-of-the-art DSM technologies and update the list of potential DSM technologies which can be used in governmental buildings.

The development of a decision making model was the aim of this research and the model has been successfully applied in ranking DSM options to provide the optimal DSM for governmental buildings in Kuwait. The research identified opportunities for further research in many other areas. The findings and techniques could be further developed to achieve the goal of improving the decision-making practices in building energy management more generally.

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Appendices

Appendix A: Phase 1 (Interview and Semi-Structured Questionnaire)

Phase 1: FACE-TO-FACE INTERVIEW

Interview record

Interview date: / /

Institute / University/ organization name:

Address:

Tel: E-mail:

Interviewee:

Title:

Years of service:

Do you consider any part of your responses to questionnaire confidential?

☐ YES ☐ NO

Note: confidentiality will be honoured, by coding responses and destroying original responses.

Interview content:

The purpose of section 1 is to meet directly the experts and discuss the following:

1. Current decision-making process dealing with selecting demand side management technologies in mosque/ school / office.
2. What are the Barriers that faced implementation of DSM in Kuwait?
3. Demand side management technologies suitable for existing buildings (mosque/ school / office).
4. Criteria to be considered when select demand side management technologies for existing buildings (mosque/ school / office).
5. Demand side management technologies suitable for new buildings (mosque/ school / office) including emerging technologies.
6. Criteria to be considered when select demand side management technologies for new buildings (mosque/ school / office).
7. Requirement of decision making model for demand side management selection.

Personal note:

Questionnaire

Date: / /

Name:

Title:

Years of experience:

Institute / University / company name:

Address:

Tel: E-mail:

Questionnaire main Purpose: to identify a list of criteria and Demand Side Management technologies, mainly questions 3,4,5,6 related directly to the main

8. There is any Current decision-making model/method dealing with selecting demand Side management technologies in Kuwait governmental buildings? (optional)

   ☐ Yes ☐ No

9. Please indicate from the list below the Barriers that could face implementing demand Side management technologies in governmental buildings in Kuwait. (optional)

☐ Energy planners are biased towards Prefer of supply side options than demand Side option.

☐ Building Regulations & Procedures

☐ Electricity Tariff structure.

☐ Lack of information for the necessity of Demand Side Management in governmental side.

☐ Lack of institutional infrastructures

☐ Oversized design.

☐ Rigid governmental purchasing procurement guidelines.

☐ Lack of expertise on energy efficiency and lack of training and awareness program.

☐ Lack of assessments method for energy efficiency equipments and appliances.

Others:

10. Please select the Demand side management technologies that suitable for existing buildings below and add what you think it is suitable.

a. Existing Mosques

A1. For HVAC:

☐ Programmable Thermostats ☐ High efficient A/Units

☐ Variable Frequency Drives ☐ Use air curtains at entrances

☐ Use of computerized Building Management Systems (BMS)

☐ Power factor correction for motors.

☐ Thermal Energy Storage.

☐ **Others …….**

☐ …………………………... ☐ …………...

☐ …………………………... ☐ …..……….

☐ …………………………... ☐ …..……….

A2. For Lighting:

☐ High efficient lighting ☐ Occupancy sensors

☐ Timers for scheduling ☐ Timers for scheduling

☐ Daylight Harvesting and using automatic dimmers

☐ Electronic ballast.

☐ **Others …….**

☐ …………………………... ☐ …………...

☐ …………………………... ☐ …………...

☐ …………………………... ☐ …………...

A3. For Building Envelope:

☐ Highly reflective glass for windows

☐ Cladding/coating the outside walls and roofs

☐ **Others …….**

☐ …………………………... ☐ ………...

☐ …………………………... ☐ …………...

☐ …………………………... ☐ …………...

b. Existing Schools

B1. For HVAC:

☐ Programmable Thermostats ☐ High efficient A/C units

☐ Variable Frequency Drives ☐ Use air curtains at entrances

☐ Use of computerized Building Management Systems (BMS)

☐ Use of micro switches installed in the windows.

☐ Thermal Energy Storage.

☐ **Others …….**

☐ …………………………... ☐ ……………………...

☐ …………………………... ☐ ……………………...

☐ …………………………... ☐ ……………………...

B2. For Lighting:

☐ High efficient lighting ☐ Occupancy sensors

☐ Timers for scheduling (Daily / Weekly / Holidays)

☐ Daylight Harvesting and using automatic dimmers

☐ After-Hours Override

☐ Use of 32W-T8 lamps and electronic ballasts instead of 40W-T12 for better lighting with energy saving

☐ **Others …….**

☐ …………………………... ☐ ………………………...

☐ …………………………... ☐ ………………………...

☐ …………………………... ☐ ………………………...

B3. For Building Envelope:

- ☐ Highly reflective glass for windows
- ☐ Cladding/coating the outside walls and roofs
- ☐ **Others …….**

☐ …………………………...	☐ ……………………...
☐ …………………………...	☐ ……………………...
☐ …………………………...	☐ ……………………...

c. Existing Offices

C1. For HVAC:

- ☐ Programmable Thermostats ☐ High efficient A/C units
- ☐ Variable Frequency Drives ☐ Use air curtains at entrances
- ☐ Use of computerized Building Management Systems (BMS)
- ☐ Use of micro switches installed in the windows
- ☐ Cooling recovery unit.
- ☐ Thermal Energy Storage.
- ☐ **Others …….**

☐ …………………………...	☐ …………...
☐ …………………………...	☐ …………...
☐ …………………………...	☐ …………...

C2. For Lighting:

- ☐ High efficient lighting ☐ Occupancy sensors
- ☐ Card Access Triggers HVAC & Lighting
- ☐ Use of office machines having less heat output
- ☐ Timers for scheduling (Daily / Weekly / Holidays)
- ☐ Daylight Harvesting and using automatic dimmers
- ☐ After-Hours Override
- ☐ Use of 32W-T8 lamps and electronic ballasts instead of 40W-T12 for better lighting with energy saving
- ☐ **Others …….**

☐ …………………………...	☐ …………...
☐ …………………………...	☐ …………...

☐ ……………………………... ☐ …………...

C3. For Building Envelope:

☐ Highly reflective glass for windows

☐ Use of double glaze glass for windows.

☐ Cladding/coating the outside walls and roofs

☐ **Others …….**

☐	…………………………...	☐	…………...
☐	…………………………...	☐	…………...
☐	…………………………...	☐	…………...

11. Criteria to be considered when selecting demand side management technologies for existing buildings and add what you think it is suitable.

☐ Flexibility for operation and maintenance.

☐ Durability and reliability

☐ Capital cost

☐ Reduction in consumption

☐ Comfort ability for users.

☐ Impact on reduction in environment (CO_2, Sox, NOx)

☐ **Others …….**

☐	…………………………...	☐	………………………...
☐	…………………………...	☐	………………………...
☐	…………………………...	☐	………………………...

12. Demand Side management technologies suitable for new buildings including emerging technologies and add what you think it is suitable.

d. New Mosques

A1. For HVAC:

☐ Programmable Thermostats ☐ High efficient A/C units

☐ Variable Frequency Drives

☐ Use of computerized Building Management Systems (BMS)

☐ Power factor correction for motors.

☐ Thermal Energy Storage.

☐ Possibility of using Natural Gas Air Conditioning systems

☐ The use of Air Curtains at the entrance(s). Blower Door Air Sealing.

☐ **Others …….**

☐ …………………………...   ☐ ………………………...

☐ …………………………...   ☐ ………………………...

☐ …………………………...   ☐ ………………………...

A2. For Lighting:

☐ High efficient lighting   ☐ Occupancy sensors

☐ Timers for scheduling   ☐ Timers for scheduling

☐ Daylight Harvesting and using automatic dimmers

☐ Electronic ballast.

☐ …………………………...   ☐ ………………………...

☐ …………………………...   ☐ ………………………...

☐ …………………………...   ☐ ………………………...

A3. For Building Envelope:

☐ Highly reflective glass for windows

☐ Cladding / coating the outside walls and roofs.

☐ Building design and orientations.

☐ **Others ……**

☐ …………………………...   ☐ ……………………...

☐ …………………………...   ☐ ……………………...

☐ …………………………...   ☐ ……………………...

e. New Schools

B1. For HVAC

☐ Programmable Thermostats ☐ High efficient A/C units

☐ Variable Frequency Drives ☐Use air curtains at entrances

☐ Use of computerized Building Management Systems (BMS)

☐ Use of micro switches installed in the windows.

☐ Thermal Energy Storage

☐ The use of Central Air-conditioning with VAV boxes and / or Heat Pumps

☐ The use of Variable Frequency Drives to optimize the power consumed by the HVAC fans

☐ **Others …….**

☐ …………………………...   ☐ ………………………...

☐ …………………………...   ☐ ………………………...

☐ …………………………...   ☐ ………………………...

B2. For Lighting:

☐ High efficient lighting   ☐ Occupancy sensors

☐ Timers for scheduling (Daily / Weekly / Holidays)

☐ Daylight Harvesting and using automatic dimmers

☐ After-Hours Override

☐ Use of 32W-T8 lamps and electronic ballasts instead of 40W-T12 for better lighting with energy saving

☐ **Others …….**

☐ …………………………...   ☐ ………………………...

☐ …………………………...   ☐ ………………………...

☐ …………………………...   ☐ ………………………...

B3. For Building Envelope:

☐ Highly reflective glass for windows

☐ Cladding/coating the outside walls and roofs

☐ **Others …….**

☐ …………………………...   ☐ ………………………...

☐ …………………………...   ☐ ………………………...

☐ …………………………...   ☐ ………………………...

f. New Offices

C1. For HVAC:

☐ Programmable Thermostats ☐ High efficient A/C units

☐ Variable Frequency Drives ☐ Use air curtains at entrances

☐ Use of computerized Building Management Systems (BMS)

☐ Use of micro switches installed in the windows

☐ Cooling recovery unit.

☐ Thermal Energy Storage.

☐ The use of Central Air-conditioning with VAV boxes and / or Heat Pumps

☐ **Others …….**

☐	…………………………...	☐	………………………...
☐	…………………………...	☐	………………………...
☐	…………………………...	☐	………………………...
☐	…………………………...	☐	………………………...

C2. For Lighting:

☐ High efficient lighting ☐ Occupancy sensors

☐ Card Access Triggers HVAC & Lighting

☐ Use of office machines having less heat output

☐ Timers for scheduling (Daily / Weekly / Holidays)

☐ Daylight Harvesting and using automatic dimmers

☐ After-Hours Override

☐ Use of 32W-T8 lamps and electronic ballasts instead of 40W-T12 for better lighting with energy saving

☐ **Others …….**

☐	…………………………...	☐	…………...
☐	…………………………...	☐	…………...

C3. For Building Envelope:

☐ Highly reflective glass for windows

☐ Use of double glaze glass for windows.

☐ Cladding/coating the outside walls and roofs

☐ **Others …….**

☐	…………………………...	☐	…………...
☐	…………………………...	☐	…………...

13. Criteria to be considering when select demand side management technologies for new buildings and add what you think it is suitable.

☐ Flexibility for operation and maintenance.

☐ Durability and reliability

☐ Capital cost

☐ Reduction in consumption

☐ Comfort ability for users.

☐ Impact on reduction in environment (CO2, Sox, NOx)

☐ **Others …….**

☐ …………………………... ☐ ………………………...

☐ …………………………... ☐ ………………………...

☐ …………………………... ☐ ………………………...

14. Do you think there is any need for decision-making model/method for selection of demands Side management technologies in Kuwait governmental buildings?

☐Yes ☐ No

☐ Justification: …………………………...

☐ …………………………...

☐ …………………………...

☐ …………………………...

Phase 1 : Semi – Structured Questionnaire Results

Note: Below results based on 28 experts judgment, (28 experts - academics (13), Owners (7), Consultants (6) and Contractors (2))

15. There is any Current decision-making model/method dealing with selecting demand Side management technologies in Kuwait governmental buildings?

Q # 1	**Academics Yes**	**Academics No**	**Owners Yes**	**Owners No**	**Consultants Yes**	**Consultants No**	**Contractors Yes**	**Contractors No**
NO. of response	-	12	-	7	-	6	-	2

2- Please indicate from the list below the Barriers that could face implementing DSM technologies in governmental buildings in Kuwait.

Question # 2	**Academics**	**Consultants**	**Owners**	**Contractors**
Energy planners are Prefer of SSM options than DSM option.	4	3	4	1
Building Regulations & Procedures	8	6	7	1
Electricity Tariff structure.	10	6	7	1
Lack of information for the necessity of DSN in governmental side.	8	3	1	2
Lack of institutional infrastructures	5	1	2	1
Oversized design.	6	6	7	-
Rigid governmental purchasing procurement guidelines.	1	-	6	-
Lack of expertise on energy efficiency, lack of training /awareness program.	8	2	3	2
Lack of assessments method for energy efficiency equipment's	5	3	5	1
Others: No incentives for private sector.	2	-	2	-
Lack of monitoring and verification programs	1	-	3	-
Improper selecting of consulting services.	1	-	-	-
Unavailability of special committee for updating standards.	1	-	-	-
Limited budget for projects and electricity demand technologies.	1	-	-	-
Delay in upgrading code of practice / energy conservation standards.	1	-	-	-
No energy services companies in local market	-	-	2	

3. Please select the Demand side management technologies that suitable for existing buildings below and add what you think it is suitable.

A. Existing Mosques	**Academics**	**Consultants**	**Owners**	**Contractors**
A1. For HVAC:				
Programmable Thermostats	11	6	7	1
High efficient A/C units	9	6	7	2
Variable Frequency Drives	8	6	4	-
Use air curtains at entrances	8	1	1	1
(BMS)	1	1	1	1
Power factor correction for motors.	5	4	7	1
Thermal Energy Storage.	-	-	-	1
Others				
Load control for A/C/ remote control	4	3	3	-
Shading for A/C Units	1	-	-	-
Tree shading for buildings	1	-	-	-
Proper maintenance	-	-	2	-
Facility engineer	-	-	1	-

A2. For Lighting:				
High efficient lighting	11	6	7	2
Occupancy sensors	10	6	5	1
Timers for scheduling	8	4	7	2
Daylight using automatic dimmers	4	1	1	2
Electronic ballast.	7	3	3	1
Others : Using daylight as possible	1	-	-	-
A3. For Building Envelope:				
Highly reflective glass for windows	12	6	7	2
Cladding/coating the outside walls and roofs	10	6	7	2
Others :				
Insulation of walls and roofs	1	-	-	-
Solar control glass for windows	1	-	-	-
Window construction (double glazing)	1	-	-	-

B. Existing Schools	**Academics**	**Consultants**	**Owners**	**Contractors**
B1. For HVAC:				
Programmable Thermostats	11	6	7	2
High efficient A/C units	9	6	7	2
Variable Frequency Drives	8	6	4	1
Use air curtains at entrances	3	-	-	1
Use of (BMS)	5	-	1	1
Use of micro switches in windows.	1	-	-	-
Thermal Energy Storage.	-	-	-	1
Others				
Load control for A/C/ remote control	3	1	3	2
Use of chillers instead of packages and / or mini split units	1	-	-	1
Proper maintenance	-	-	1	-
Facility engineer	-	-	1	-

B2. For Lighting:				
High efficient lighting	10	6	5	2
Occupancy sensors	9	4	-	2
Timers for scheduling	4	6	5	2
Daylight Harvesting and using automatic dimmers	3	1	-	1
After-Hours Override	4	-	1	2
Use of 32W-T8 lamps and electronic ballasts instead of 40W-T12	11	4	4	2
B3. For Building Envelope:				
Highly reflective glass for windows	11	6	7	2
Cladding/coating the outside walls/ roofs	9	6	7	2
Insulation of walls and roofs	1	-	-	-
Solar control glass for windows	1	-	-	-
Window construction (double glazing)	1	-	-	-

C. Existing Offices	**Academics**	**Consultants**	**Owners**	**Contractors**
C1. For HVAC:				
Programmable Thermostats	11	6	7	2
High efficient A/C units	9	6	7	2
Variable Frequency Drives	11	6	7	1
Use air curtains at entrances	4	4	2	-
Use of (BMS)	7	4	4	-
Use of micro switches installed in the windows.	1	-	-	1
Thermal Energy Storage.	1	-	1	1
Cooling recovery unit.	6	4	4	2
Others				
Load control for A/C	3	2	1	2
Proper maintenance	1	-	1	-
C2. For Lighting:				
High efficient lighting	11	6	7	2

Occupancy sensors	11	6	3	2
Timers for scheduling	10	6	7	2
Card Access Triggers HVAC & Lighting	1	0	-	-
Use of office machines having less heat output	1	0	-	1
Daylight using automatic dimmers	1	0	-	1
After-Hours Override	3	3	-	1
Use of 32W-T8 lamps and electronic ballasts instead of 40W-T12	6	2	4	1
C3. For Building Envelope:				
Highly reflective glass for windows	9	6	7	2
Cladding/coating the outside walls/roofs	10	6	7	2
Use of double glaze glass for windows.	9	6	7	2

4. Criteria to be considered when selecting demand side management technologies for existing buildings and add what you think it is suitable.

Criteria	**Academics**	**Consultants**	**Owners**	**Contractors**
Flexibility for operation and maintenance.	11	6	7	2
Durability and reliability	8	4	5	2
Capital cost	8	6	7	2
Reduction in consumption	11	6	7	1
Comfort ability for users.	10	4	4	2
Impact on reduction in environment (CO2, Sox, NOx)	6	6	5	1
Others:				
Payback period	3	-	-	-
Technology life	2	-	-	-
Ease of implementation	3	-	-	1
After sales services	-	1	1	-

5. Demand Side management technologies suitable for new buildings including emerging technologies and add what you think it is suitable.

A. New Mosques	**Academics**	**Consultants**	**Owners**	**Contractors**
A1. For HVAC:				
Programmable Thermostats	7	6	7	1
High efficient A/C units	9	6	7	2
Variable Frequency Drives	5	4	4	1
Use of (BMS)	10	6	7	2
Power factor correction for motors.	2	4	1	-
Thermal Energy Storage.	1	4	-	1
Possibility of using Natural Gas A/C systems	-	-	-	1
Use air curtains at entrances	8	4	-	1
Others				
Load control for A/C/ remote control	4	1	1	-
Use of under floor air distribution system	1	-	-	-
Shading of A/C equipment's	1	-	-	-
CO2 Sensor	-	1	-	-
Economizer cycle	-	1	-	-

A2. For Lighting:				
High efficient lighting	12	6	7	2
Occupancy sensors	12	6	-	1
Timers for scheduling	12	6	7	1
Daylight Harvesting and using automatic dimmers	2	-	-	1
Electronic ballast.	9	4	4	1
A3. For Building Envelope:				
Highly reflective glass for windows	11	6	7	2
Cladding/coating the outside walls and roofs	10	6	7	2
Building design and orientation	6	3	7	1
Shading of windows frame	1	-	-	-

B. New Schools	Academics	Consultants	Owners	Contractors
B1. For HVAC:				
Programmable Thermostats	11	6	6	-
High efficient A/C units	12	6	7	2
Variable Frequency Drives	6	6	7	-
Use air curtains at entrances	7	-	-	1
Use of (BMS)	5	4	6	1
Use of micro switches installed in the windows.	-	-	-	-
Thermal Energy Storage.	5	4	6	1
The use of Central Air-conditioning with VAV boxes and / or Heat Pumps	7	4	2	2
The use of Variable Frequency Drives to optimize the power consumed by the HVAC fans	2	1	-	-
Others				
Load control for A/C	6	2	1	2
Shading of A/C equipment's	3	-	-	-
Proper maintenance	-	-	1	-
Facility engineer	-	-	1	-
B2. For Lighting:				

High efficient lighting	12	6	7	2
Occupancy sensors	7	6	2	-
Timers for scheduling	12	6	7	1
Daylight Harvesting and using automatic dimmers	8	4	-	1
After-Hours Override	8	3	-	1
Use of 32W-T8 lamps and electronic ballasts instead of 40W-T12	10	3	4	1
Others : using daylight as possible	1	-	-	-
B3. For Building Envelope:				
Highly reflective glass for windows	12	4	7	2
Cladding/coating the outside walls and roofs	12	4	7	2

C. New Offices	**Academics**	**Consultants**	**Owners**	**Contractors**
C1. For HVAC:				
Programmable Thermostats	9	4	6	1
High efficient A/C units	12	6	7	2
Variable Frequency Drives	9	4	7	2
Use air curtains at entrances	8	4	-	-
Use of (BMS)	13	6	7	1
Use of micro switches in windows.	2	-	-	1
Thermal Energy Storage.	9	4	4	1
Cooling recovery unit.	8	2	4	-
The use of Central A/C with VAV boxes and / or Heat Pumps	6	-	-	2
Others				
Load control for A/C	6	2	1	2
District cooling	1	-	-	-
Proper maintenance	-	-	1	-
Facility engineer	-	-	1	-
C2. For Lighting:				

High efficient lighting	11	6	7	2
Occupancy sensors	4	2	-	2
Timers for scheduling	9	6	7	2
Card Access Triggers HVAC & Lighting	6	4	-	1
Use of office machines having less heat output	3	-	-	-
Daylight Harvesting and using automatic dimmers	7	4	-	2
After-Hours Override	5	1	-	1
Use of 32W-T8 lamps and electronic ballasts instead of 40W-T12	6	4	3	2
C3. For Building Envelope:				
Highly reflective glass for windows	10	6	7	2
Cladding/coating the outside walls and roofs	12	6	7	2
Use of double glaze glass for windows.	10	3	7	2

6. Criteria to be considering when select demand side management technologies for new buildings and add what you think it is suitable.

Criteria	**Academics**	**Consultants**	**Owners**	**Contractors**
Flexibility for operation and maintenance.	12	6	7	2
Durability and reliability	8	4	6	2
Capital cost	9	6	7	2
Reduction in consumption	11	6	7	1
Comfort ability for users.	11	6	7	2
Impact on reduction in environment (CO2, Sox, NOx)	7	4	5	1
Others:				
Payback period	3	-	-	1
Life cycle cost	1	-	-	
Ease of implementation	3	-	-	1
After sales services	-	1	-	-

Availability of technology	-	-	1	-

7. Do you think there is any need for decision-making model/method for selection of demands Side management technologies in Kuwait governmental buildings?

Q#7	**Academics Yes**	**Academics No**	**Consultants Yes**	**Consultants No**	**Owners Yes**	**Owners No**	**Contractors Yes**	**Contractors No**
Answers	13		6		7		2	

Appendix B: Phase 2 (Delphi Method)

Delphi method questionnaire

Date: / /

Name:

Title:

Years of experience:

Institute / University / company name:

Address:

Tel: E-mail:

Main purpose of questionnaire: to determine the importance Demand Side Management alternatives (DSM) and Criteria that affect selecting optimal demand side management alternatives for the following existing and new buildings:

1- School.

2- Religious place.

3- Office.

Note: please answer the following questions based only on your personal experience and there is no right or wrong answer

1- Building Type: School

1.1 Please determine the importance of demand side management alternatives for existing school building, kindly rank your choice from very important (9) to very unimportant (1). Select one box by clicking it per row.

Table 1.1: Existing school building DSM alternatives

#	DSM alternatives	The importance of DSM alternatives								
		1	2	3	4	5	6	7	8	9
		Very unimportant		Unimportant		Normal		Important		Very important
1	Install Programmable Thermostats	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Replace existing A/C by High efficient	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Proper maintenace for A/C	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Retrofit Cooling recovery unit	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Install Remote control for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Shading for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Install Variable Frequency Drives	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Sensors for supply and return air temperature	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Install High Efficiency Lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐
10	Install Time of use control	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Install Occupancy Sensors	☐	☐	☐	☐	☐	☐	☐	☐	☐
12	Building Management Systems	☐	☐	☐	☐	☐	☐	☐	☐	☐
13	Install of air curtains at entrances	☐	☐	☐	☐	☐	☐	☐	☐	☐
14	Install Highly reflective glass for windows	☐	☐	☐	☐	☐	☐	☐	☐	☐
15	Install Cladding/coating the outside walls and roofs	☐	☐	☐	☐	☐	☐	☐	☐	☐
16	Install Power factor correction	☐	☐	☐	☐	☐	☐	☐	☐	☐

1.2 Please determine the importance of demand side management alternatives for new school Building. Kindly rank your choice from very important (9) to very unimportant (1), Select one box by clicking it per row.

Table 1.2: New school building DSM alternatives

	DSM alternatives	**The importance of DSM alternatives**								
#		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Very unimportant		Unimportant		Normal		Important		Very important
1	Install Programmable Thermostats	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Install High efficient A/C units	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Install Variable Frequency Drives	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	use of Central Air-conditioning with VAV boxes	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Install Cooling recovery unit	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Install Remote control for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Shading for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Install of air curtains at entrances	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Install Sensors for supply and return air temperature	☐	☐	☐	☐	☐	☐	☐	☐	☐
10	Proper maintenace for A/C	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Install thermal Energy Storage for A/C	☐	☐	☐	☐	☐	☐	☐	☐	☐
12	Install High Efficiency Lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐
13	Install Time of use control	☐	☐	☐	☐	☐	☐	☐	☐	☐
14	Install Occupancy Sensors	☐	☐	☐	☐	☐	☐	☐	☐	☐
15	Install Building Management Systems	☐	☐	☐	☐	☐	☐	☐	☐	☐
16	Install Power factor correction.	☐	☐	☐	☐	☐	☐	☐	☐	☐
17	Install Highly reflective windows	☐	☐	☐	☐	☐	☐	☐	☐	☐
18	Install Cladding/coating the outside walls and roofs	☐	☐	☐	☐	☐	☐	☐	☐	☐

1.3 Please determine the importance of criteria that affect in selection the demand side management alternatives for existing/ new school buildings. Kindly rank your choice from very important (9) to very unimportant (1), Select one box by clicking it per row.

Table 1.3: Criteria for selecting DSM in existing/ new school buildings

#	**Criteria**	**The importance of Criteria**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Very unimportant		Unimportant		Normal		Important		Very important
1	Flexibility for operation and maintenance.	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Durability and reliability	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Capital cost	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Reduction in consumption	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Comfort ability for users.	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Impact on environment (CO2, SOx, NOx)	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Payback period	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Ease of implementation	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Technology life cycle	☐	☐	☐	☐	☐	☐	☐	☐	☐
10	Availability of technology	☐	☐	☐	☐	☐	☐	☐	☐	☐

2- Building Type: religious place

2.1 Please determine the importance of demand side management alternatives for existing religious place building. Kindly rank your choice from very important (9) to very unimportant (1), Select one box by clicking it per row.

Table 2.1: Existing religious place building DSM alternatives

	DSM alternatives	**The importance of DSM alternatives**								
#		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Very unimportant		Unimportant		Normal		Important		Very important
1	Install Programmable Thermostats	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	High efficient A/C units	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Install Variable Frequency Drives	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Retrofit Cooling recovery unit	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Install Remote control for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Shading for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Install of air curtains at entrances	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Install Sensors for supply and return air temperature	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Proper maintenace for A/C	☐	☐	☐	☐	☐	☐	☐	☐	☐
10	Install High Efficiency Lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Install Time of use control - lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐
12	Install Occupancy Sensors.	☐	☐	☐	☐	☐	☐	☐	☐	☐
13	Install Power Factor Correction.	☐	☐	☐	☐	☐	☐	☐	☐	☐
14	Building Management Systems	☐	☐	☐	☐	☐	☐	☐	☐	☐
15	Install Highly reflective glass for windows	☐	☐	☐	☐	☐	☐	☐	☐	☐
16	Install Cladding/coating the outside walls and roofs	☐	☐	☐	☐	☐	☐	☐	☐	☐

2.2 Please determine the importance of demand side management alternatives for new religious place buildings. Kindly rank your choice from very important (9) to very unimportant (1), Select one box by clicking it per row.

Table 2.2: New religious place building DSM alternatives

	DSM alternatives	**The importance of DSM alternatives**								
#		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Very unimportant		Unimportant		Normal		Important		Very important
1	Install Programmable Thermostats	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Install High efficient A/C units	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Install Variable Frequency Drives	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Install Cooling recovery unit	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Install Remote control for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Shading for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Install of air curtains at entrances	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Install Sensors for supply and return air temperature	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Proper maintenace for A/C	☐	☐	☐	☐	☐	☐	☐	☐	☐
10	Install A/C thermal Energy Storage	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Install High Efficiency Lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐
12	Time of use control for lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐
13	Install Occupancy Sensors	☐	☐	☐	☐	☐	☐	☐	☐	☐
14	Install Power factor correction.	☐	☐	☐	☐	☐	☐	☐	☐	☐
15	Building Management Systems	☐	☐	☐	☐	☐	☐	☐	☐	☐
16	High reflective glass for windows	☐	☐	☐	☐	☐	☐	☐	☐	☐
17	Install Cladding/coating the outside walls and roofs	☐	☐	☐	☐	☐	☐	☐	☐	☐

2.3 Please determine the importance of criteria that affect in selection the demand side management alternatives for existing/ new religious buildings. Kindly rank your choice from very important (9) to very unimportant (1), Select one box by clicking it per row.

Table 2.3: Criteria for selecting DSM in existing/ new religious place buildings

#	**Criteria**	**The importance of Criteria**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Very unimportant		Unimportant		Normal		Important		Very important
1	Flexibility for operation and maintenance.	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Durability and reliability	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Capital cost	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Reduction in consumption	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Comfort ability for users.	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Impact on environment (CO_2, SO_x, NO_x)	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Payback period	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Ease of implementation	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Technology life cycle	☐	☐	☐	☐	☐	☐	☐	☐	☐
10	Availability of technology	☐	☐	☐	☐	☐	☐	☐	☐	☐

3- Building Type: Offices

3.1 Please determine the importance of demand side management alternatives for existing office Building. Kindly rank your choice from very important (9) to very unimportant (1), Select one box by clicking it per row.

Table 3.1: Existing office building DSM alternatives

	DSM alternatives	**The importance of DSM alternatives**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Very unimportant		Unimportant		Normal		Important		Very important
1	Install Programmable Thermostats	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Install high efficient A/C units	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Variable Frequency Drives	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Retrofit Cooling recovery unit	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Remote control for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Shading for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Use of air curtains at entrances	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Sensors for supply and return air temperature	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Proper maintenace for A/C	☐	☐	☐	☐	☐	☐	☐	☐	☐
10	Install High Efficiency Lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Install time of use control - lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐
12	Install Occupancy Sensors	☐	☐	☐	☐	☐	☐	☐	☐	☐
13	Building Management Systems	☐	☐	☐	☐	☐	☐	☐	☐	☐
14	Card Access HVAC & Lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐
15	Install Power Factor Correction	☐	☐	☐	☐	☐	☐	☐	☐	☐
16	Highly reflective glass for windows	☐	☐	☐	☐	☐	☐	☐	☐	☐
17	Cladding/coating the outside walls and roofs	☐	☐	☐	☐	☐	☐	☐	☐	☐

3.2 Please determine the importance of demand side management alternatives for new office building, kindly rank your choice from very important (9) to very unimportant (1), and Select one box by clicking it per row.

Table 3.2: New office building DSM alternatives

	DSM alternatives	**The importance of DSM alternatives**								
#		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Very unimportant		Unimportant		Normal		Important		Very important
1	Install Programmable Thermostats	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Install High efficient A/C units	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Install Variable Frequency Drives	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Install Cooling recovery unit	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Install Remote control for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Shading for A/C Units	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Install of air curtains at entrances	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Install Sensors for supply and return air temperature	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Proper maintenace for A/C	☐	☐	☐	☐	☐	☐	☐	☐	☐
10	use of Central A/C with VAV boxes	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Install A/C thermal Energy Storage	☐	☐	☐	☐	☐	☐	☐	☐	☐
12	Install High Efficiency Lighting.	☐	☐	☐	☐	☐	☐	☐	☐	☐
13	Install time of use control - lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐
14	Install Occupancy Sensors	☐	☐	☐	☐	☐	☐	☐	☐	☐
15	Building Management Systems	☐	☐	☐	☐	☐	☐	☐	☐	☐
16	Install Power factor correction.	☐	☐	☐	☐	☐	☐	☐	☐	☐
17	Install Highly reflective glass for windows	☐	☐	☐	☐	☐	☐	☐	☐	☐
18	Install Cladding/coating the outside walls and roofs	☐	☐	☐	☐	☐	☐	☐	☐	☐

3.3 Please determine the importance of criteria that affect in selection the demand side management alternatives existing/ new office buildings. Kindly rank your choice from very important (9) to very unimportant (1), Select one box by clicking it per row.

Table 3.3: Criteria for selecting DSM in existing/ new office buildings

#	Criteria	The importance of Criteria								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
		Very unimportant		Unimportant		Normal		Important		Very important
1	Flexibility for operation and maintenance.	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Durability and reliability	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Capital cost	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Reduction in consumption	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Comfort ability for users.	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Impact on environment (CO2, SOx, NOx)	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Payback period	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Ease of implementation	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Technology life cycle	☐	☐	☐	☐	☐	☐	☐	☐	☐
10	Availability of technology	☐	☐	☐	☐	☐	☐	☐	☐	☐

Data results for Delphi

Below results represent the data obtained from Delphi questionnaires in Round 1 and Round 2 for the Academic expert's panel as an example of other groups:

1- Academic group

1-1 Existing School DSM Alternatives R1.
1-2 Existing School DSM Alternatives R2.
1-3 New School DSM Alternatives R1.
1-4 New School DSM Alternatives R2
1-5 Criteria School R1.
1-6 Criteria School R2.
1-7 Existing religion place DSM Alternatives R1.
1-8 Existing religion place DSM Alternatives R2.
1-9 New Religion place DSM Alternatives R1.
1-10 New Religion place DSM Alternatives R1.
1-11 Criteria religion place R1.
1-12 Criteria religion place R2.
1-13 Existing Office building DSM Alternatives R1.
1-14 Existing Office building DSM Alternatives R2.
1-15 New Office building DSM Alternatives R1.
1-16 New Office building DSM Alternatives R2
1-17 Criteria Office building R1.
1-18 Criteria Office building R2.

1- Academic Group:

1-1 Existing School DSM Alternatives R1

	Install high efficiency lighting	Install Programmable Thermostat	Use time of use control	Install Variable Frequency Drives VFD	Proper maintenance for A C	Install power factor correction
N	10	10	10	10	10	10
Mean	8.4000	8.1000	7.9000	6.9000	6.6000	6.6000
Median	8.5000	8.0000	8.0000	7.0000	6.5000	7.0000
Mode	9.00	9.00	8.00	7.00	5.00	5.00(a)
Std. Deviation	.69921	.87560	.73786	1.28668	1.64655	1.26491
Variance	.489	.767	.544	1.656	2.711	1.600

a Multiple modes exist. The smallest value is shown

1-2 Existing School DSM Alternatives R2

		Install_high_efficiency_lighting	Install_Programmable_Thermostat	Use_time_of_use_control	Install_Variable_Frequency_Drives__ VFD _	Install_power_factor_correction	Install_remote_control_for_A_C_units
N	Valid	10	10	10	10	10	10
	Missing	0	0	0	0	0	0
Mean		8.5000	8.3000	8.0000	7.2000	7.0000	6.8000
Median		8.5000	8.0000	8.0000	7.0000	7.0000	7.0000
Mode		8.00(a)	8.00	8.00	7.00	7.00	7.00
Std. Deviation		.52705	.67495	.66667	.91894	.94281	1.22927
Variance		.278	.456	.444	.844	.889	1.511

a Multiple modes exist. The smallest value is shown

1-3 New School DSM Alternatives R1.

		Install_High_Efficiency_Lighting	Install_High_efficient_A_C_units	Install_Building_Management_Systems__BMS_	Install_Variable_Frequency_Drives	Install_Programmable_Thermostats	Install_Remote_control_for_A_C_Units
N	Valid	10	10	10	10	10	10
	Missing	0	0	0	0	0	0
Mean		8.8000	8.7000	8.1000	7.9000	7.5000	7.4000
Median		9.0000	9.0000	8.0000	8.0000	7.5000	7.0000
Mode		9.00	9.00	9.00	9.00	7.00(a)	7.00
Std. Deviation		.42164	.48305	.87560	1.10050	.84984	.96609
Variance		.178	.233	.767	1.211	.722	.933

a Multiple modes exist. The smallest value is show

1-4 New School DSM Alternatives R2.

		Install_High_Efficiency_Lighting	Install_High_efficient_A_C_units	Install_Building_Management_Systems__BMS_	Install_Variable_Frequency_Drives	Install_Programmable_Thermostats	Install_Remote_control_for_A_C_Units
N	Valid	10	10	10	10	10	10
	Missing	0	0	0	0	0	0
Mean		8.8000	8.7000	8.2000	7.9000	7.5000	7.4000
Median		9.0000	9.0000	8.0000	8.0000	7.5000	7.0000
Mode		9.00	9.00	8.00(a)	9.00	7.00(a)	7.00
Std. Deviation		.42164	.48305	.78881	1.10050	.84984	.96609
Variance		.178	.233	.622	1.211	.722	.933

a Multiple modes exist. The smallest value is shown

1-5 Criteria School R1.

		Reduction_in_consumption	Capital_cost	Ease_of_implementation	Impact_on_environment	Comfort_ability_for_users
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		9.0000	8.5000	8.3000	7.9000	7.6000
Median		9.0000	9.0000	8.5000	8.0000	7.5000
Std. Deviation		.00000	1.26930	.82327	.73786	1.26491
Variance		.000	1.611	.678	.544	1.600

1-6 Criteria School R2.

		Reduction_in_consumption	Ease_of_implementation	Impact_on_environment	Comfort_ability_for_users	Capital_cost
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		8.4000	8.3000	7.9000	7.8000	7.8000
Median		8.5000	8.0000	8.0000	7.5000	8.0000
Mode		9.00	8.00	8.00	7.00(a)	7.00(a)
Std. Deviation		.69921	.48305	.73786	1.13529	1.03280
Variance		.489	.233	.544	1.289	1.067

a Multiple modes exist. The smallest value is shown

1-7 Existing religion place DSM Alternatives R1

		Install_High_Efficiency_Lighting	Install_Programmable_Thermostats	Install_Time_of_use_control__lighting	Replace_existing_A_C_by_High_efficient_A_C_units	Install_Remote_control_for_A_C_Units	Install_Variable_Frequency_Drives
N	Valid	10	10	10	10	10	10
	Missing	0	0	0	0	0	0
Mean		8.3000	8.2000	7.8000	7.2000	7.0000	6.6000
Median		8.0000	8.5000	8.0000	7.5000	7.5000	7.0000
Mode		8.00	9.00	8.00	8.00	8.00	7.00
Std. Deviation		.67495	.91894	.63246	1.47573	1.76383	1.07497
Variance		.456	.844	.400	2.178	3.111	1.156

a Multiple modes exist. The smallest value is shown

1-8 Existing religion place DSM Alternatives R2 :

		Install_High_Efficiency_Lighting	Install_Programmable_Thermostats	Install_Time_of_use_control__lighting	Install_Power_Factor_Correction_	Install_Remote_control_for_A_C_Units	Install_Variable_Frequency_Drives
N	Valid	10	10	10	10	10	10
	Missing	0	0	0	0	0	0
Mean		8.3000	8.2000	7.8000	7.1000	7.0000	6.8000
Median		8.0000	8.5000	8.0000	7.0000	7.5000	7.0000
Mode		8.00	9.00	8.00	7.00	8.00	7.00
Std. Deviation		.67495	.91894	.63246	.73786	1.76383	.91894
Variance		.456	.844	.400	.544	3.111	.844

a Multiple modes exist. The smallest value is shown

1-9 New Religion place DSM Alternatives R1 :

		Install_High_Efficiency_Lighting	Install_High_efficient_A_C_units	Install_Building_Management_Systems__BMS_	Install_Variable_Frequency_Drives	Time_of_use_control_for_lighting	Install_Remote_control_for_A_C_Units
N	Valid	10	10	10	10	10	10
	Missing	0	0	0	0	0	0
Mean		8.8000	8.7000	7.5000	7.4000	7.4000	7.2000
Median		9.0000	9.0000	8.0000	7.0000	7.0000	7.0000
Mode		9.00	9.00	7.00(a)	7.00	7.00	7.00
Std. Deviation		.42164	.48305	1.77951	1.07497	.84327	.91894
Variance		.178	.233	3.167	1.156	.711	.844

a Multiple modes exist. The smallest value is shown

1-10 New Religion place DSM Alternatives R2:

		Install_High_Efficiency_Lighting	Install_High_efficient_A_C_units	Install_Building_Management_Systems__BMS_	Time_of_use_control_for_lighting	Install_Variable_Frequency_Drives	Install_Remote_control_for_A_C_Units
N	Valid	10	10	10	10	10	10
	Missing	0	0	0	0	0	0
Mean		8.8000	8.7000	7.9000	7.4000	7.2000	7.2000
Median		9.0000	9.0000	8.0000	7.0000	7.0000	7.0000
Mode		9.00	9.00	7.00	7.00	7.00	7.00
Std. Deviation		.42164	.48305	.87560	.84327	.91894	.91894
Variance		.178	.233	.767	.711	.844	.844

a Multiple modes exist. The smallest value is shown

1-11 Criteria Religion place R1:

		Reduction_in_consumption	Capital_cost	Ease_of_implementation	Comfort_ability_for_users	Durability_and_reliability
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		8.6000	8.3000	8.3000	8.0000	7.6000
Median		9.0000	8.0000	8.0000	8.0000	7.5000
Mode		9.00	8.00	8.00	9.00	7.00(a)
Std. Deviation		.51640	.67495	.67495	1.05409	1.17379
Variance		.267	.456	.456	1.111	1.378

1-12 Criteria Religion place R2 :

		Reduction_in_consumption	Ease_of_implementation	Capital_cost	Comfort_ability_for_users	Impact_on_environment
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		8.6000	8.4000	8.3000	8.0000	7.7000
Median		9.0000	8.0000	8.0000	8.0000	8.0000
Mode		9.00	8.00	8.00	9.00	8.00
Std. Deviation		.51640	.51640	.67495	1.05409	.67495
Variance		.267	.267	.456	1.111	.456

a Multiple modes exist. The smallest value is shown

1-13 Existing Office building DSM Alternatives R1:

		Install_High_Efficiency_Lighting	Install_Programmable_Thermostats	Install_time_of_use_control__lighting	Install_Power_Factor_Correction	Install_high_efficient_A_C_units	Proper_maintenace_for_A_C
N	Valid	10	10	10	10	10	10
	Missing	0	0	0	0	0	0
Mean		8.4000	7.5000	7.4000	7.1000	7.0000	7.0000
Median		8.5000	8.0000	7.5000	7.0000	7.0000	7.0000
Mode		9.00	8.00	7.00(a)	7.00(a)	7.00	7.00
Std. Deviation		.69921	1.71594	1.07497	.99443	1.63299	1.41421
Variance		.489	2.944	1.156	.989	2.667	2.000

a Multiple modes exist. The smallest value is shown

1-14 Existing Office building DSM Alternatives R2 :

		Install_High_Efficiency_Lighting	Install_Programmable_Thermostats	Install_time_of_use_control__lighting	Install_Building_Management_Systems__BMS_	Remote_control_for_A_C_Units	Install_Power_Factor_Correction
N	Valid	10	10	10	10	10	10
	Missing	0	0	0	0	0	0
Mean		8.4000	7.9000	7.6000	7.5000	7.4000	7.3000
Median		8.5000	8.0000	7.5000	7.0000	7.5000	7.0000
Mode		9.00	8.00	7.00	7.00	8.00	7.00
Std. Deviation		.69921	.73786	.69921	.97183	.69921	.67495
Variance		.489	.544	.489	.944	.489	.456

a Multiple modes exist. The smallest value is shown

1-15 New Office building DSM Alternatives R1 :

		Install_High_efficient_A_C_units	Install_High_Efficiency_Lighting_	Install_Building_Management_Systems__BMS_	Install_thermal_Energy_Storage_for_A_C_instead_of_Conventional_A	Install_Variable_Frequency_Drives	Install_Remote_control_for_A_C
N	Valid	10	10	10	10	10	10
	Missing	0	0	0	0	0	0
Mean		8.9000	8.7000	8.6000	7.8000	7.4000	7.4000
Median		9.0000	9.0000	9.0000	8.0000	7.0000	7.0000
Mode		9.00	9.00	9.00	7.00(a)	6.00(a)	7.00
Std. Deviation		.31623	.48305	.69921	.78881	1.26491	.84327
Variance		.100	.233	.489	.622	1.600	.711

a Multiple modes exist. The smallest value is shown

1-16 New Office building DSM Alternatives R2:

		Install_High_efficient_A_C_units	Install_High_Efficiency_Lighting_	Install_Building_Management_Systems__BMS_	Install_thermal_Energy_Storage_for_A_C_instead_of_Conventional_A	Install_Remote_control_for_A_C	Install_Programmable_Thermostats
N	Valid	10	10	10	10	10	10
	Missing	0	0	0	0	0	0
Mean		8.9000	8.7000	8.6000	7.8000	7.4000	7.2000
Median		9.0000	9.0000	9.0000	8.0000	7.0000	7.0000
Mode		9.00	9.00	9.00	7.00(a)	7.00	7.00
Std. Deviation		.31623	.48305	.69921	.78881	.84327	.91894
Variance		.100	.233	.489	.622	.711	.844

a Multiple modes exist. The smallest value is shown

1-17 Criteria Office building R1:

		Reduction_in_consumption	Ease_of_implementation	Comfort_ability_for_users	Impact_on_environment	Capital_cost
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		8.3000	8.2000	7.8000	7.7000	7.6000
Median		8.5000	8.0000	7.5000	8.0000	8.0000
Mode		9.00	8.00	7.00(a)	8.00	8.00(a)
Std. Deviation		.82327	.63246	1.13529	1.15950	1.34990
Variance		.678	.400	1.289	1.344	1.822

a Multiple modes exist. The smallest value is shown

1-18 Criteria Office building R2 :

		Reduction_in_consumption	Capital_cost	Ease_of_implementation	Impact_on_environment	Comfort_ability_for_users
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		9.0000	8.5000	8.3000	7.9000	7.6000
Median		9.0000	9.0000	8.5000	8.0000	7.5000
Mode		9.00	9.00	9.00	8.00	7.00
Std. Deviation		.00000	1.26930	.82327	.73786	1.26491
Variance		.000	1.611	.678	.544	1.600

a Multiple modes exist. The smallest value is shown

DELPHI STATISTICAL RESULTS FOR ACADEMICS (ROUND 1) FOR EXISTING SCHOOL DSM ALTERNATIVES

II. For existing Schools

No.	DSM Option	The Importance of DSM Alternatives (Round 1) Academics Group											
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD
1	**Install Programmable Thermostat**	9	9	9	8	7	7	8	9	8	7	8.1	0.8307
2	**Replace existing A/C by high efficient A/C units**	9	4	7	3	5	8	4	9	6	5	6	2.0494
3	**Proper maintenance for A/C**	9	8	9	5	7	5	5	6	7	5	6.6	1.562
4	**Retrofit cooling recovery unit**	7	3	7	5	3	3	4	3	7	5	4.7	1.6763
5	**Install remote control for A/C units**	6	4	3	8	7	8	6	7	7	8	6.4	1.6248
6	**Shading for A/C units**	3	8	1	5	3	3	5	4	3	4	3.9	1.7578
7	**Install Variable Frequency Drives (VDF)**	7	9	5	5	7	8	8	7	6	7	6.9	1.2207
8	**Install sensors for supply and return air temperature**	7	8	3	5	1	5	5	4	4	5	4.7	1.8466
9	**Install high efficiency lighting**	9	9	9	8	7	8	8	9	9	8	8.4	0.6633
10	**Use time of use control**	9	8	9	8	7	8	7	8	8	7	7.9	0.7
11	**Install occupancy sensors**	9	5	7	7	7	6	6	5	7	6	6.5	1.118
12	**Install building management system (BMS)**	7	8	3	5	3	5	6	7	5	5	5.4	1.562
13	**Install air curtains at entrances**	5	7	3	2	3	1	2	5	3	4	3.5	1.6882
14	**Install highly reflective glass for windows**	7	5	7	7	6	2	6	7	7	6	6	1.4832
15	**Install cladding/coating the outside walls and roofs**	7	8	3	2	1	2	5	3	4	3	3.8	2.1354
16	**Install power factor correction**	7	8	5	5	5	7	8	7	6	8	6.6	1.2

II. For existing Schools

No.	DSM Option	The Importance of DSM Alternatives (Round 2) Academics Group												
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD	Rank
1	**Install high efficiency lighting**	9	9	9	8	8	8	8	9	9	8	8.5	0.5	1
2	**Install Programmable Thermostat**	9	9	9	8	8	7	8	9	8	8	8.3	0.6403	2
3	**Use time of use control**	9	8	9	8	8	8	7	8	8	7	8	0.6325	3
4	**Install Variable Frequency Drives (VDF)**	7	9	7	6	7	8	8	7	6	7	7.2	0.8718	4
5	**Install power factor correction**	7	8	7	7	5	7	8	7	6	8	7	0.8944	5
6	**Install remote control for A/C units**	6	4	7	8	7	8	6	7	7	8	6.8	1.1662	6
7	**Install occupancy sensors**	7	5	7	7	7	6	6	5	7	6	6.3	0.781	7
8	**Proper maintenance for A/C**	7	8	7	5	7	5	5	6	7	5	6.2	1.077	8
9	**Install highly reflective glass for windows**	7	5	7	7	6	4	6	7	7	6	6.2	0.9798	9
10	**Install building management system (BMS)**	7	8	6	5	5	5	6	7	5	5	5.9	1.044	10
11	**Replace existing A/C by high efficient A/C units**	7	4	7	3	5	8	6	6	6	5	5.7	1.4177	11
12	**Install sensors for supply and return air temperature**	7	8	3	5	4	5	5	4	4	5	5	1.4142	12
13	**Retrofit cooling recovery unit**	7	3	4	5	3	3	4	3	5	5	4.2	1.249	13
14	**Shading for A/C units**	3	8	4	5	3	3	5	4	3	4	4.2	1.4697	14
15	**Install cladding/coating the outside walls and roofs**	7	8	3	2	4	2	5	3	4	3	4.1	1.9209	15
16	**Install air curtains at entrances**	5	5	3	2	3	1	2	5	3	4	3.3	1.3454	16

DELPHI STATISTICAL RESULTS FOR ACADEMICS (ROUND 1) FOR NEW SCHOOL DSM ALTERNATIVES

II. For New Schools

No.	DSM Option	The Importance of DSM Alternatives (Round 1)											
		Academics Group											
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD
1	**Install Programmable Thermostats**	9	8	7	8	7	8	7	8	7	6	7.5	0.81
2	**Install High efficient A/C units**	9	9	9	9	8	9	8	8	9	9	8.7	0.46
3	**Install Variable Frequency Drives**	9	9	9	7	8	9	7	6	8	7	7.9	1.04
4	**use of Central Air-conditioning with VAV boxes**	7	9	7	7	7	8	7	6	7	7	7.2	0.75
5	**Install Cooling recovery unit**	5	5	9	9	7	9	7	6	8	6	7.1	1.51
6	**Install Remote control for A/C Units**	7	7	7	9	7	8	9	7	7	6	7.4	0.92
7	**Shading for A/C Units**	3	8	1	5	3	3	5	4	3	5	4	1.79
8	**Install of air curtains at entrances**	4	8	3	3	3	3	5	4	3	5	4.1	1.51
9	**Install Sensors for supply and return air temperature**	7	8	5	5	6	3	5	4	5	5	5.3	1.35
10	**Proper maintenance for A/C**	9	8	7	5	6	5	5	4	6	7	6.2	1.47
11	**Install thermal Energy Storage for A/C instead of Conventional A/C**	3	4	9	9	8	9	7	8	8	8	7.3	2.00
12	**Install High Efficiency Lighting**	9	8	9	9	9	9	8	9	9	9	8.8	0.40
13	**Install Time of use control**	9	8	7	4	6	8	7	6	7	8	7	1.34
14	**Install Occupancy Sensors**	9	2	7	5	6	5	7	6	5	7	5.9	1.76

15	**Install Building Management Systems (BMS)**	7	9	7	9	7	9	8	8	9	8	8.1	0.83
16	**Install Power factor correction.**	7	9	5	5	3	3	5	4	6	6	5.3	1.73
17	**Install Highly reflective windows**	9	9	9	5	3	7	7	6	8	8	7.1	1.87
18	**Install Cladding/coating the outside walls and roofs**	7	9	3	7	3	7	8	6	8	8	6.6	1.96

For Criteria Evaluation (Existing/New Schools)

No.	CRITERIA	The Importance of Criteria (Round 1) Academics Group											
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD
1	**Flexibility for Operation and Maintenance**	9	8	5	7	9	5	6	5	6	7	6.7	1.49
2	**Durability and reliability**	9	9	5	7	9	5	7	6	7	7	7.1	1.45
3	**Capital cost**	6	8	5	7	9	8	9	8	7	9	7.6	1.28
4	**Reduction in consumption**	9	9	7	7	9	8	8	8	9	9	8.3	0.78
5	**Comfort ability for users**	9	9	9	9	7	7	6	8	7	7	7.8	1.08
6	**Impact on environment**	9	8	7	5	7	8	8	8	8	9	7.7	1.1
7	**Payback period**	9	6	5	5	5	7	8	6	8	7	6.6	1.36
8	**Ease of implementation**	9	8	7	8	9	8	9	8	8	8	8.2	0.6
9	**Technology life cycle**	6	8	5	5	3	5	4	3	5	3	4.7	1.49
10	**Availabilty of technology**	9	8	7	8	5	6	7	6	5	3	6.4	1.69

No.	CRITERIA	The Importance of Criteria (Round 2) Academics Group												
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD	Rank
1	**Reduction in consumption**	9	9	8	7	9	8	8	8	9	9	8.4	0.66	1
2	**Ease of implementation**	9	8	8	8	9	8	9	8	8	8	8.3	0.46	2
3	**Impact on environment**	9	8	7	7	7	8	8	8	8	9	7.9	0.7	4
4	**Comfort ability for users**	9	9	9	9	7	7	6	8	7	7	7.8	1.08	3
5	**Capital cost**	6	8	7	7	9	8	9	8	7	9	7.8	0.98	5
6	**Durability and reliability**	9	9	7	7	9	5	7	6	7	7	7.3	1.27	6

7	**Flexibility for Operation and Maintenance**	9	8	7	7	9	5	6	5	6	7	6.9	1.37	7
8	**Payback period**	9	6	5	5	5	7	8	6	8	7	6.6	1.36	8
9	**Availabilty of technology**	9	8	7	8	5	6	7	6	5	3	6.4	1.69	9
10	**Technology life cycle**	6	8	5	5	3	5	4	3	5	3	4.7	1.49	10

DELPHI STATISTICAL RESULTS FOR ACADEMICS (ROUND 1) FOR EXISTING RELIGION PLACE DSM ALTERNATIVES

III. For Existing religion place

No.	DSM Option	The Importance of DSM Alternatives (Round 1)											
		Academics Group											
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD
1	**Install Programmable Thermostats**	9	9	9	7	7	9	8	9	8	7	8.2	0.87
2	**Replace existing A/C by High efficient A/C units**	9	8	7	7	6	8	8	9	5	5	7.2	1.4
3	**Install Variable Frequency Drives**	6	8	5	7	7	8	5	7	7	6	6.6	1.02
4	**Retrofit Cooling recovery unit**	5	3	7	3	3	7	5	3	6	5	4.7	1.55
5	**Install Remote control for A/C Units**	9	5	7	3	7	8	8	7	8	8	7	1.67
6	**Shading for A/C Units**	3	8	1	2	2	2	5	4	3	4	3.4	1.91
7	**Install of air curtains at entrances**	7	8	7	2	2	3	5	5	3	4	4.6	2.06
8	**Install Sensors for supply and return air temperature**	7	8	3	2	1	5	5	4	5	2	4.2	2.14
9	**Proper maintenance for A/C**	9	8	5	5	5	5	7	6	6	5	6.1	1.37
10	**Install High Efficiency Lighting**	9	8	9	8	7	8	8	9	9	8	8.3	0.64
11	**Install Time of use control - lighting**	9	8	7	7	8	8	8	8	8	7	7.8	0.6
12	**Install Occupancy Sensors.**	9	1	3	6	6	6	5	6	7	7	5.6	2.11
13	**Install Power Factor Correction.**	7	8	5	3	8	7	8	7	6	6	6.5	1.5
14	**Install Building Management Systems (BMS)**	5	8	3	3	5	5	6	5	5	6	5.1	1.37

15	**Install Highly reflective glass for windows**	7	7	7	5	5	3	7	8	7	5	6.1	1.45
16	**Install Cladding/coating the outside walls and roofs**	7	8	3	2	2	3	5	7	4	3	4.4	2.11

DELPHI STATISTICAL RESULTS FOR ACADEMICS (ROUND 2) FOR EXISTING RELIGION PLACE DSM ALTERNATIVES

III. For Existing religion place

No.	DSM Option	The Importance of DSM Alternatives (Round 2)												
		Academics Group												
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD	Rank
1	**Install High Efficiency Lighting**	9	8	9	8	7	8	8	9	9	8	8.3	0.64	1
2	**Install Programmable Thermostats**	9	9	9	7	7	9	8	9	8	7	8.2	0.87	2
3	**Install Time of use control - lighting**	9	8	7	7	8	8	8	8	8	7	7.8	0.6	3
4	**Install Power Factor Correction.**	7	8	7	7	8	7	8	7	6	6	7.1	0.7	6
5	**Install Remote control for A/C Units**	9	5	7	3	7	8	8	7	8	8	7	1.67	4
6	**Install Variable Frequency Drives**	6	8	7	7	7	8	5	7	7	6	6.8	0.87	5
7	**Replace existing A/C by High efficient A/C units**	7	8	7	7	6	7	7	7	5	5	6.6	0.92	7
8	**Install Highly reflective glass for windows**	7	7	7	5	5	6	7	8	7	5	6.4	1.02	8
9	**Proper maintenance for A/C**	7	8	5	5	5	5	7	6	6	5	5.9	1.04	9

10	**Install Occupancy Sensors.**	9	1	3	6	6	6	5	6	7	7	5.6	2.11	10
11	**Install Building Management Systems (BMS)**	5	8	3	3	5	5	6	5	5	6	5.1	1.37	11
12	**Retrofit Cooling recovery unit**	5	3	7	3	3	7	5	3	6	5	4.7	1.55	12
13	**Install of air curtains at entrances**	7	8	7	2	2	3	5	5	3	4	4.6	2.06	13
14	**Install Cladding/coating the outside walls and roofs**	7	8	3	2	2	3	5	7	4	3	4.4	2.11	14
15	**Install Sensors for supply and return air temperature**	7	8	3	2	1	5	5	4	5	2	4.2	2.14	15
16	**Shading for A/C Units**	3	8	1	2	2	2	5	4	3	4	3.4	1.91	16

DELPHI STATISTICAL RESULTS FOR ACADEMICS (ROUND 1) FOR NEW RELIGION PLACE DSM ALTERNATIVES

IV. For New religion place building

No.	DSM Option	The Importance of DSM Alternatives (Round 1) Academics Group											
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD
1	**Install Programmable Thermostats**	9	5	6	8	7	7	6	8	7	6	6.9	1.1358
2	**Install High efficient A/C units**	9	9	9	9	8	9	8	8	9	9	8.7	0.4583
3	**Install Variable Frequency Drives**	6	9	9	7	8	8	7	7	7	6	7.4	1.0198
4	**Install Cooling recovery unit**	3	5	7	8	7	8	7	6	7	6	6.4	1.4283
5	**Install Remote control for A/C Units**	7	7	8	9	6	7	8	7	6	7	7.2	0.8718
6	**Shading for A/C Units**	3	8	2	5	4	3	4	5	5	4	4.3	1.5524
7	**Install of air curtains at entrances**	7	8	3	3	4	3	4	5	7	5	4.9	1.7578
8	**Install Sensors for supply and return air temperature**	7	8	6	5	6	3	4	5	6	5	5.5	1.3601
9	**Proper maintenance for A/C**	9	8	7	5	7	5	4	5	5	7	6.2	1.5362
10	**Install thermal Energy Storage for A/C instead of Conventional A/C**	3	5	7	8	8	8	7	6	8	7	6.7	1.5524
11	**Install High Efficiency Lighting**	9	9	9	9	9	9	8	8	9	9	8.8	0.4
12	**Time of use control for lighting**	7	9	7	6	7	7	8	8	7	8	7.4	0.8
13	**Install Occupancy Sensors**	7	1	7	6	7	6	7	5	5	6	5.7	1.7349
14	**Install Power factor correction.**	7	8	6	5	4	4	5	4	5	6	5.4	1.2806
15	**Install Building Management Systems (BMS)**	3	9	8	9	7	9	7	8	7	8	7.5	1.6882
16	**Install Highly reflective glass for windows**	7	9	8	5	4	6	8	6	7	8	6.8	1.4697
17	**Install Cladding/coating the outside walls and roofs**	7	9	4	5	4	7	8	6	7	8	6.5	1.6279

DELPHI STATISTICAL RESULTS FOR ACADEMICS (ROUND 2) FOR NEW RELIGION PLACE DSM ALTERNATIVES

IV. For New religion place building

No.	DSM Option	The Importance of DSM Alternatives (Round 2) Academics Group												
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD	Rank
1	**Install High Efficiency Lighting**	9	9	9	9	9	9	8	8	9	9	8.8	0.4	1
2	**Install High efficient A/C units**	9	9	9	9	8	9	8	8	9	9	8.7	0.4583	2
3	**Install Building Management Systems (BMS)**	7	9	8	9	7	9	7	8	7	8	7.9	0.8307	3
4	**Time of use control for lighting**	7	9	7	6	7	7	8	8	7	8	7.4	0.8	4
5	**Install Variable Frequency Drives**	6	9	7	7	8	8	7	7	7	6	7.2	0.8718	4
6	**Install Remote control for A/C Units**	7	7	8	9	6	7	8	7	6	7	7.2	0.8718	5
7	**Install Highly reflective glass for windows**	7	9	8	5	4	6	8	6	7	8	6.8	1.4697	7
8	**Install Programmable Thermostats**	7	5	6	8	7	7	6	8	7	6	6.7	0.9	6
9	**Install thermal Energy Storage for A/C instead of Conventional A/C**	3	5	7	8	8	8	7	6	8	7	6.7	1.5524	8
10	**Install Cladding/coating the outside walls and roofs**	7	9	4	5	4	7	8	6	7	8	6.5	1.6279	9
11	**Install Cooling recovery unit**	3	5	7	8	7	8	7	6	7	6	6.4	1.4283	10
12	**Proper maintenance for A/C**	9	8	7	5	7	5	4	5	5	7	6.2	1.5362	11
13	**Install Occupancy Sensors**	7	1	7	6	7	6	7	5	5	6	5.7	1.7349	12
14	**Install Sensors for supply and return air temperature**	7	8	6	5	6	3	4	5	6	5	5.5	1.3601	13

15	**Install Power factor correction.**	7	8	6	5	4	4	5	4	5	6	5.4	1.2806	14
16	**Install of air curtains at entrances**	7	8	3	3	4	3	4	5	7	5	4.9	1.7578	15
17	**Shading for A/C Units**	3	8	2	5	4	3	4	5	5	4	4.3	1.5524	16

DELPHI STATISTICAL RESULTS FOR ACADEMICS (ROUND 1 AND 2) FOR SCHOOLS BUILDING

DELPHI STATISTICAL RESULTS

For Criteria Evaluation (Existing/New Offices)

No.	CRITERIA	The Importance of Criteria (Round 1)											
		Academics Group											
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD
1	Flexibility for Operation and Maintenance	7	8	6	7	9	6	6	7	8	7	7.1	0.943398
2	Durability and reliability	9	8	6	7	9	6	7	7	9	8	7.6	1.113553
3	Capital cost	7	8	8	8	9	8	9	9	9	8	8.3	0.640312
4	Reduction in consumption	9	9	8	8	9	8	9	9	9	8	8.6	0.489898
5	Comfort ability for users	9	9	9	9	6	7	7	8	8	8	8	1
6	Impact on environment	9	8	7	6	8	7	8	8	7	7	7.5	0.806226
7	Payback period	7	8	5	5	6	7	8	6	6	7	6.5	1.024695
8	Ease of implementation	9	8	7	8	9	8	9	8	9	8	8.3	0.640312
9	Technology life cycle	7	8	5	6	3	6	5	7	7	6	6	1.341641
10	Availabilty of technology	9	8	7	8	5	6	6	7	7	6	6.9	1.135782

No.	CRITERIA	The Importance of Criteria (Round 2)												
		Academics Group												
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	AVG	SD	Rank
1	Reduction in consumption	9	9	8	8	9	8	9	9	9	8	8.6	0.489898	1
2	Ease of implementation	9	8	8	8	9	8	9	8	9	8	8.4	0.489898	2
3	Capital cost	7	8	8	8	9	8	9	9	9	8	8.3	0.640312	2
4	Comfort ability for users	9	9	9	9	6	7	7	8	8	8	8	1	3
5	Impact on environment	9	8	8	7	8	7	8	8	7	7	7.7	0.640312	5
6	Durability and reliability	9	8	6	7	9	6	7	7	9	8	7.6	1.113553	4

7	**Flexibility for Operation and Maintenance**	7	8	6	7	9	6	6	7	8	7	7.1	0.943398	6
8	**Availabilty of technology**	9	8	7	8	5	6	6	7	7	6	6.9	1.135782	7
9	**Payback period**	7	8	5	5	6	7	8	6	6	7	6.5	1.024695	8
10	**Technology life cycle**	7	8	5	6	3	6	5	7	7	6	6	1.341641	9

DELPHI STATISTICAL RESULTS FOR ACADEMICS (ROUND 1) FOR EXISTING OFFICE DSM ALTERNATIVES

V. For Existing Offices

No.	DSM Option	The Importance of DSM Alternatives (Round 1)											
		Academics Group											
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD
1	Install Programmable Thermostats	9	8	3	7	7	8	9	8	8	8	7.5	1.6279
2	Install high efficient A/C units	9	7	7	5	4	8	9	7	8	6	7	1.5492
3	Variable Frequency Drives	9	8	5	5	5	7	8	7	7	6	6.7	1.3454
4	Retrofit Cooling recovery unit	7	6	7	5	4	7	7	6	7	6	6.2	0.9798
5	Remote control for A/C Units	7	6	3	7	8	8	7	7	8	8	6.9	1.4457
6	Shading for A/C Units	3	8	1	3	2	6	5	2	4	5	3.9	2.0224
7	Use of air curtains at entrances	7	8	5	3	1	5	6	5	4	4	4.8	1.8868
8	Sensors for supply and return air temperature	7	8	3	5	2	5	5	6	5	3	4.9	1.7578
9	Proper maintenace for A/C	9	9	5	5	7	7	6	7	8	7	7	1.3416
10	Install High Efficiency Lighting	9	8	9	9	7	8	9	8	9	8	8.4	0.6633
11	Install time of use control – lighting	9	8	5	7	7	8	8	7	8	7	7.4	1.0198
12	Install Occupancy Sensors	9	5	7	7	7	6	6	7	6	7	6.7	1.005
13	Install Building Management Systems (BMS)	9	9	5	3	5	7	7	7	8	8	6.8	1.833

14	Card Access Triggers HVAC & Lighting	6	8	3	2	1	5	4	5	3	4	4.1	1.9209
15	Install Power Factor Correction	8	8	5	7	8	7	8	7	6	7	7.1	0.9434
16	Highly reflective glass for windows	9	7	7	7	5	7	8	7	7	6	7	1
17	Cladding/coating the outside walls and roofs	9	8	3	5	3	6	6	5	5	4	5.4	1.8547

DELPHI STATISTICAL RESULTS FOR ACADEMICS (ROUND 2) FOR EXISTING OFFICE DSM ALTERNATIVES

V. For Existing Offices

No.	DSM Option	The Importance of DSM Alternatives (Round 2)												
		Academics Group												
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD	Rank
1	Install High Efficiency Lighting	9	8	9	9	7	8	9	8	9	8	8.4	0.6633	1
2	Install Programmable Thermostats	9	8	7	7	7	8	9	8	8	8	7.9	0.7	2
3	Install time of use control - lighting	9	8	7	7	7	8	8	7	8	7	7.6	0.6633	3
4	Install Building Management Systems (BMS)	9	9	7	7	6	7	7	7	8	8	7.5	0.922	7
5	Remote control for A/C Units	7	6	8	7	8	8	7	7	8	8	7.4	0.6633	6
6	Install Power Factor Correction	8	8	7	7	8	7	8	7	6	7	7.3	0.6403	4
7	Install high efficient A/C units	9	7	7	5	4	8	9	7	8	6	7	1.5492	5
8	Proper maintenance for A/C	9	9	5	5	7	7	6	7	8	7	7	1.3416	6
9	Highly reflective glass for windows	9	7	7	7	5	7	8	7	7	6	7	1	7
10	Variable Frequency Drives	9	8	5	5	5	7	8	7	7	6	6.7	1.3454	8
11	Install Occupancy Sensors	9	5	7	7	7	6	6	7	6	7	6.7	1.005	9
12	Retrofit Cooling recovery unit	7	6	7	5	4	7	7	6	7	6	6.2	0.9798	10

13	Cladding/coating the outside walls and roofs	9	8	3	5	3	6	6	5	5	4	5.4	1.8547	11
14	Sensors for supply and return air temperature	7	8	3	5	2	5	5	6	5	3	4.9	1.7578	12
15	Use of air curtains at entrances	7	8	5	3	1	5	6	5	4	4	4.8	1.8868	13
16	Shading for A/C Units	3	8	4	3	2	6	5	2	4	5	4.2	1.7776	14
17	Card Access Triggers HVAC & Lighting	6	8	3	2	1	5	4	5	3	4	4.1	1.9209	15

DELPHI STATISTICAL RESULTS FOR ACADEMICS (ROUND 1) FOR NEW OFFICE DSM ALTERNATIVES

VI. For New Offices

No.	DSM Option	The Importance of DSM Alternatives (Round 1)											
		Academics Group											
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD
1	Install Programmable Thermostats	9	7	5	7	6	8	6	8	7	7	7	1.095445
2	Install High efficient A/C units	9	9	9	9	9	9	8	9	9	9	8.9	0.3
3	Install Variable Frequency Drives	9	9	9	7	6	8	6	7	6	7	7.4	1.2
4	Install Cooling recovery unit	8	5	3	7	6	8	7	6	7	7	6.4	1.428286
5	Install Remote control for A/C	7	6	7	7	9	7	8	8	7	8	7.4	0.8
6	Shading for A/C Units	3	8	9	3	4	3	5	5	7	6	5.3	2.051828
7	Install of air curtains at entrances	7	8	7	5	5	7	5	5	6	5	6	1.095445
8	Install Sensors for supply and return air temperature	7	8	5	3	4	5	5	6	7	5	5.5	1.431782
9	Proper maintenace for A/C	9	9	9	7	4	5	8	6	7	5	6.9	1.75784
10	use of Central A/C +VAV boxes	9	8	5	5	4	7	7	6	6	5	6.2	1.469694
11	Install thermal Energy Storage for A/C instead of Conventional A/C	7	8	7	7	9	7	8	8	9	8	7.8	0.748331
12	Install High Efficiency Lighting.	9	8	9	9	9	9	8	8	9	9	8.7	0.458258

13	Install time of use control - lighting	9	8	3	7	5	7	6	7	7	8	6.7	1.615549
14	Install Occupancy Sensors	9	4	9	7	5	7	7	6	6	5	6.5	1.565248
15	Install Building Management Systems (BMS)	9	9	9	9	9	9	7	8	9	8	8.6	0.663325
16	Install Power factor correction.	8	8	9	5	5	6	7	5	6	8	6.7	1.417745
17	Install Highly reflective windows	9	8	9	7	5	7	8	6	7	7	7.3	1.187434
18	Install Insulation walls and roofs	7	8	5	7	5	7	8	6	7	8	6.8	1.077033

DELPHI STATISTICAL RESULTS FOR ACADEMICS (ROUND 2) FOR NEW OFFICE DSM ALTERNATIVES

VI. For New Offices

No.	DSM Option	The Importance of DSM Alternatives (Round 2)												
		Academics Group												
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD	Rank
1	Install High efficient A/C units	9	9	9	9	9	9	8	9	9	9	8.9	0.3	1
2	Install High Efficiency Lighting.	9	8	9	9	9	9	8	8	9	9	8.7	0.458258	2
3	Install Building Management Systems (BMS)	9	9	9	9	9	9	7	8	9	8	8.6	0.663325	3
4	Install thermal Energy Storage for A/C instead of Conventional A/C	7	8	7	7	9	7	8	8	9	8	7.8	0.748331	4
5	Install Remote control for A/C	7	6	7	7	9	7	8	8	7	8	7.4	0.8	5
6	Install Programmable Thermostats	9	7	7	7	6	8	6	8	7	7	7.2	0.87178	6
7	Install Variable Frequency Drives	9	9	7	7	6	7	6	7	6	7	7.1	1.044031	7
8	Install Highly reflective windows	9	8	7	7	5	7	8	6	7	7	7.1	1.044031	8
9	Install time of use control - lighting	9	8	6	7	5	7	6	7	7	8	7	1.095445	9
10	Install Insulation walls and roofs	7	8	5	7	5	7	8	6	7	8	6.8	1.077033	10
11	Proper maintenace for A/C	9	9	7	7	4	5	8	6	7	5	6.7	1.615549	11
12	Install Power factor	8	8	9	5	5	6	7	5	6	8	6.7	1.417745	12

	correction.													
13	Install Cooling recovery unit	8	5	6	7	6	8	7	6	7	7	6.7	0.9	13
14	Install Occupancy Sensors	9	4	9	7	5	7	7	6	6	5	6.5	1.565248	14
15	use of Central A/C +VAV boxes	9	8	5	5	4	7	7	6	6	5	6.2	1.469694	15
16	Install of air curtains at entrances	7	8	7	5	5	7	5	5	6	5	6	1.095445	16
17	Install Sensors for supply and return air temperature	7	8	5	3	4	5	5	6	7	5	5.5	1.431782	17
18	Shading for A/C Units	3	8	9	3	4	3	5	5	7	6	5.3	2.051828	18

DELPHI STATISTICAL RESULTS FOR ACADEMICS (ROUND 1 AND 2) FOR OFFICE BUILDING

DELPHI STATISTICAL RESULTS

For Criteria Evaluation (Existing/New Offices)

No.	CRITERIA	The Importance of Criteria (Round 1)											
		Academics Group											
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD
1	**Reduction in consumption**	9	9	9	9	9	9	9	9	9	9	9	0
2	**Capital cost**	9	8	5	9	9	9	9	9	9	9	8.5	1.204
3	**Ease of implementation**	9	9	7	8	9	7	8	9	8	9	8.3	0.781
4	**Impact on environment**	9	9	7	7	8	8	7	8	8	8	7.9	0.7
5	**Comfort ability for users**	9	9	9	7	5	7	7	7	8	8	7.6	1.2
6	**Durability and reliability**	9	8	5	7	6	5	8	8	8	8	7.2	1.327
7	**Flexibility for Operation and Maintenance**	9	8	5	7	5	5	8	7	8	8	7	1.414
8	**Payback period**	9	8	5	5	8	5	7	7	7	8	6.9	1.375
9	**Technology life cycle**	9	8	5	5	7	5	6	7	7	8	6.7	1.345
10	**Availabilty of technology**	9	9	7	5	5	5	6	7	7	7	6.7	1.418

No.	CRITERIA	The Importance of Criteria (Round 2)												
		Academics Group												
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp.5	Exp. 6	Exp. 7	Exp. 8	Exp.9	Exp.10	Average	SD	Rank
1	**Reduction in consumption**	9	9	9	9	9	9	9	9	9	9	9	0	1
2	**Capital cost**	9	8	5	9	9	9	9	9	9	9	8.5	1.204	2
3	**Ease of implementation**	9	9	7	8	9	7	8	9	8	9	8.3	0.781	3
4	**Impact on environment**	9	9	7	7	8	8	7	8	8	8	7.9	0.7	4
5	**Comfort ability for users**	9	9	9	7	5	7	7	7	8	8	7.6	1.2	5
6	**Durability and reliability**	9	8	5	7	6	5	8	8	8	8	7.2	1.327	6
7	**Flexibility for Operation and Maintenance**	9	8	5	7	5	5	8	7	8	8	7	1.414	7
8	**Payback period**	9	8	5	5	8	5	7	7	7	8	6.9	1.375	8

9	**Technology life cycle**	9	8	5	5	7	5	6	7	7	8	6.7	1.345	9
10	**Availabilty of technology**	9	9	7	5	5	5	6	7	7	7	6.7	1.418	9

Appendix C: Phase 3 (AHP Method)

AHP Questionnaire

Date: / /

Name:

Title:

Years of experience:

Institute / University / company name:

Address:

Tel: E-mail:

Index

Introduction:

The purpose of this survey is to collect information about:

The relative importance of each criterion when evaluating different demand side management technologies in existing/new selected government buildings types (i.e schools, religious places and offices). -1

The preferred technology with respect to each individual criterion. -2

One collected, this information will be analysed based on the Analytic Hierarchy Process (AHP) method, to identify a priority order for demand side management technologies in existing and new selected government buildings types (i.e schools, religious places and offices). -3

Instruction:

Only two parameters are compared at a time, and the relative importance between the two will be asked.

The answer will have a form such as:

(I think "A" is strongly more important compared to "B" with respect to the selection best demand side management technology so that I give "A" a point 5)

Sometimes the relative importance is hard to be expressed as absolute measurement, but this study employs the quantitative judgment rather than qualitative one such as "**very important"** or "**strongly important"**. When you judge the relative importance between two, the use of discrete 9-point scales suggested by Satty (the author of the analytic hierarchy process) will be helpful. **First judge the verbal expression, then translate into a score using the table below.**

Table 1: Fundamental scale for pair-wise comparisons:

Verbal scale	Numerical Rating
Equally important	1
Equally to moderately	2
Moderately more important, likely or preferred	3
Moderately to strongly	4
Strongly more important, likely or preferred	5
Strongly to very Strongly	6
Very strongly more important, likely or preferred	7
Very strongly to extremely	8
Extremely more important, likely or preferred	9

Example: Below is the blank answer sheet in which the relative importance between parameters A and B is compared.

1- Compare A and B

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	(A) More important									(B) More important								
A	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	B

If you think the factor A is <u>strongly more important</u> than B in with respect to the objective, then you will mark the answer sheet as shown below.

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	(A) More important									(B) More important								
A	9 ☐	8 ☐	7 ☐	6 ☐	5 ■	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	B

Note: please answer the following questions based only on your personal experience and there is no right or wrong answer

AHP Questionnaire

Office building

1- Existing office building - This section of questionnaire is composed of two parts:

I- **Pair-wise comparison for decision Criteria of existing office building**.
II- **Pair-wise comparison for decision alternatives of existing office building.**

I- **Pair-wise comparison for decision Criteria of existing office building**.

#	Decision Criteria:
1	**Reduction in consumption**
2	**Capital cost**
3	**Ease of implementation**
4	**Impact on environment**
5	**Comfort ability for users**

1-Indicate below the level of importance for each two corresponding criteria in terms of selecting the best demand side management technologies in **Existing office** building.

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Ease of implementation
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Impact on environment
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Impact on environment
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Impact on environment	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Impact on environment	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Comfort ability for users	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost

II- Pair-wise comparison for decision alternatives of existing office building.

#	Decision alternatives:
1	Install High Efficiency Lighting
2	Install Programmable Thermostats
3	Install Time of use control - lighting
4	Install Building management systems (BMS)
5	Install Power Factor Correction.
6	Install Remote control for A/C Units

1-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for existing office in terms of reduction in consumption

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
									Criterion: Reduction in consumption									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building management system
									Criterion: Reduction in consumption									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Reduction in consumption									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
									Criterion: Reduction in consumption									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
									Criterion: Reduction in consumption									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building management system
									Criterion: Reduction in consumption									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Reduction in consumption									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control – lighting
									Criterion: Reduction in consumption									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
									Criterion: Reduction in consumption									

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control – lighting
	Criterion: Reduction in consumption																	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Reduction in consumption																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Reduction in consumption																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Reduction in consumption																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Reduction in consumption																	

2-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing Office** in terms of **ease of implementation**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
							Criterion:	Ease of implementation										
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building management system
							Criterion:	Ease of implementation										
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
							Criterion:	Ease of implementation										
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
							Criterion:	Ease of implementation										
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
							Criterion:	Ease of implementation										
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building management system
							Criterion:	Ease of implementation										
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
							Criterion:	Ease of implementation										
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
							Criterion:	Ease of implementation										
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
							Criterion:	Ease of implementation										

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Ease of implementation																	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Ease of implementation																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Ease of implementation																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Ease of implementation																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Ease of implementation																	

3-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **Existing office** in terms of **Impact on environment**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building management system
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building management system
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Impact on environment																	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Impact on environment																	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Impact on environment																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Impact on environment																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Impact on environment																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Impact on environment																	

4-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing office** in terms of **Comfort ability for users**.

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
					Criterion:		Comfort ability for users											
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building management system
					Criterion:		Comfort ability for users											
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
					Criterion:		Comfort ability for users											
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
					Criterion:		Comfort ability for users											
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
					Criterion:		Comfort ability for users											
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building management system
					Criterion:		Comfort ability for users											
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
					Criterion:		Comfort ability for users											
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
					Criterion:		Comfort ability for users											
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
					Criterion:		Comfort ability for users											

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	

5-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing office** in terms of **Capital Cost**.

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Capital Cost																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building management system
	Criterion: Capital Cost																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Capital Cost																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Capital Cost																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building management system
	Criterion: Capital Cost																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Capital Cost																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Capital Cost																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Capital Cost																	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Capital Cost																	
Building management system	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Capital Cost																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	

2- New office building – This section of questionnaire is composed of two parts:

I- **Pair-wise comparison for decision Criteria of New office building**.
II- **Pair-wise comparison for decision alternatives of new office building.**

I- Pair-wise comparison for decision Criteria of new office building.

#	Decision Criteria:
1	Reduction in consumption
2	Capital cost
3	Ease of implementation
4	Impact on environment
5	Comfort ability for users

1-Indicate below the level of importance for each two corresponding criteria in terms of selecting the best demand side management technologies in **new office** building.

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Ease of implementation
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Impact on environment
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Impact on environment
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Impact on environment	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Impact on environment	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Comfort ability for users	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost

II- Pair-wise comparison analysis for decision alternatives for New Office building

#	Decision alternatives:
1	Install High Efficiency Lighting
2	Install High efficient A/C units
3	Install Building Management Systems (BMS)
4	Install thermal Energy Storage
5	Install Programmable Thermostats
6	Install Remote control for A/C Units

1-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for existing office in terms of reduction in consumption

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
									Criterion: Reduction in consumption									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
									Criterion: Reduction in consumption									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
									Criterion: Reduction in consumption									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
									Criterion: Reduction in consumption									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Reduction in consumption									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
									Criterion: Reduction in consumption									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
									Criterion: Reduction in consumption									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
									Criterion: Reduction in consumption									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Reduction in consumption									

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Reduction in consumption	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Reduction in consumption	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Reduction in consumption	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
Install thermal Energy Storage	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Reduction in consumption	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
Install thermal Energy Storage	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Reduction in consumption	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Reduction in consumption	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units

2-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new office building** in terms of **ease of implementation**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
	Criterion: Ease of implementation																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
	Criterion: Ease of implementation																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Ease of implementation																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
	Criterion: Ease of implementation																	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Ease of implementation																	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
Install thermal Energy Storage	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Ease of implementation																	
Install thermal Energy Storage	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	

3-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new office building** in terms of **Impact on environment**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
									Criterion: Impact on environment									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
									Criterion: Impact on environment									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
									Criterion: Impact on environment									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
									Criterion: Impact on environment									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Impact on environment									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
									Criterion: Impact on environment									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
									Criterion: Impact on environment									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
									Criterion: Impact on environment									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Impact on environment									

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

Building Management Systems (BMS)	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Criterion: Impact on environment	Install thermal Energy Storage
Building Management Systems (BMS)	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Criterion: Impact on environment	Programmable Thermostats
Building Management Systems (BMS)	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Criterion: Impact on environment	Remote control for A/C Units
Install thermal Energy Storage	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Criterion: Impact on environment	Programmable Thermostats
Install thermal Energy Storage	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Criterion: Impact on environment	Remote control for A/C Units
Programmable Thermostats	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Criterion: Impact on environment	Remote control for A/C Units

4-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new office building** in terms of **Comfort ability for users**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
									Criterion: Comfort ability for users									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
									Criterion: Comfort ability for users									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
									Criterion: Comfort ability for users									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
									Criterion: Comfort ability for users									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Comfort ability for users									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
									Criterion: Comfort ability for users									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
									Criterion: Comfort ability for users									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
									Criterion: Comfort ability for users									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Comfort ability for users									

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
									Criterion: Comfort ability for users									
Building	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Programmable

Management Systems (BMS)	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Criterion: Comfort ability for users	Thermostats
Building Management Systems (BMS)	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Criterion: Comfort ability for users	Remote control for A/C Units
Install thermal Energy Storage	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Criterion: Comfort ability for users	Programmable Thermostats
Install thermal Energy Storage	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Criterion: Comfort ability for users	Remote control for A/C Units
Programmable Thermostats	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Criterion: Comfort ability for users	Remote control for A/C Units

5-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new office building** in terms of **Capital cost**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Install thermal Energy Storage
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
Install thermal Energy Storage	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
Install thermal Energy Storage	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Capital Cost	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units

AHP Questionnaire
Religion building

Existing Religion Building This Questionnaire is composed of two parts:

- **III- Pair-wise comparison for decision Criteria of existing Religion building.**
- **IV- Pair-wise comparison for decision alternatives of existing Religion building**.

I-**Pair-wise comparison for decision Criteria of existing Religion building**

#	**Decision Criteria:**
1	Reduction in consumption
2	Ease of implementation
3	Impact on environment
4	Comfort ability for users
5	Capital cost

1-Indicate below the level of importance for each two corresponding criteria in terms of selecting the best demand side management technologies in **Existing Religion**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Ease of implementation
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Impact on environment
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Impact on environment
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Impact on environment	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Impact on environment	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Comfort ability for users	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost

II-Pair-wise comparison for decision alternatives of existing Religion building

#	Decision alternatives:
1	Install High Efficiency Lighting
2	Install Programmable Thermostats
3	Install Time of use control - lighting
4	Install Variable Frequency Drives
5	Install Power Factor Correction.
6	Install Remote control for A/C Units

1-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing religion** in terms of **reduction in consumption**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
									Criterion: Reduction in consumption									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
									Criterion: Reduction in consumption									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Reduction in consumption									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
									Criterion: Reduction in consumption									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
									Criterion: Reduction in consumption									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
									Criterion: Reduction in consumption									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Reduction in consumption									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
									Criterion: Reduction in consumption									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
									Criterion: Reduction in consumption									

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Reduction in consumption																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Reduction in consumption																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Reduction in consumption																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Reduction in consumption																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Reduction in consumption																	

2-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing religion** in terms **Ease of implementation**

	Extremely		Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
							Criterion:	Ease of implementation										
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
							Criterion:	Ease of implementation										
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
							Criterion:	Ease of implementation										
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
							Criterion:	Ease of implementation										
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
							Criterion:	Ease of implementation										
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
							Criterion:	Ease of implementation										
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
							Criterion:	Ease of implementation										
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
							Criterion:	Ease of implementation										
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
							Criterion:	Ease of implementation										

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Ease of implementation																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Ease of implementation																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Ease of implementation																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Ease of implementation																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Ease of implementation																	

3-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing religion** in terms **Impact on environment**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
									Criterion: Impact on environment									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
									Criterion: Impact on environment									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Impact on environment									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
									Criterion: Impact on environment									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
									Criterion: Impact on environment									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
									Criterion: Impact on environment									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Impact on environment									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
									Criterion: Impact on environment									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
									Criterion: Impact on environment									

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Impact on environment																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Impact on environment																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Impact on environment																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Impact on environment																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Impact on environment																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Impact on environment																	

4-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing religion** in terms **Comfort ability for users**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Comfort ability for users																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	

5-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing religion** in terms **Capital Cost**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Capital Cost																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Capital Cost																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Capital Cost																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Capital Cost																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Capital Cost																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Capital Cost																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Capital Cost																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Capital Cost																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Capital Cost																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Capital Cost																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	

I-**Pair-wise comparison for decision Criteria of new Religion building**

#	**Decision Criteria:**
1	Reduction in consumption
2	Ease of implementation
3	Impact on environment
4	Comfort ability for users
5	Capital cost

1-Indicate below the level of importance for each two corresponding criteria in terms of selecting the best demand side management technologies in **new Religion building**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Ease of implementation
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Impact on environment
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Impact on environment
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Impact on environment	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Impact on environment	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Comfort ability for users	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost

III- **Pair-wise comparison for decision alternatives for new religion Building**

#	Decision alternatives:
1	Install High Efficiency Lighting
2	Install High efficient A/C units
3	Install Building Management Systems (BMS)
4	Install Variable Frequency Drives
5	TOU control - lighting
6	Install Remote control for A/C Units

1- Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new religion** in terms of **reduction in consumption**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
	Criterion: Reduction in consumption																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
	Criterion: Reduction in consumption																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
	Criterion: Reduction in consumption																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Reduction in consumption																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
	Criterion: Reduction in consumption																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
	Criterion: Reduction in consumption																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Reduction in consumption																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
	Criterion: Reduction in consumption																	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Reduction in consumption																	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	
Variable Frequency Drives	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Reduction in consumption																	
Variable Frequency Drives	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	

2- Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new religion** in terms of **Ease of implementation**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
	Criterion: Ease of implementation																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
	Criterion: Ease of implementation																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Ease of implementation																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
	Criterion: Ease of implementation																	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Ease of implementation																	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
Variable Frequency Drives	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Ease of implementation																	
Variable Frequency Drives	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	

3- Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new religion** in terms of **Impact on environment**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐ Criterion: Impact on environment	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
	Criterion: Impact on environment																	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Impact on environment																	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Impact on environment																	
Variable Frequency Drives	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Impact on environment																	
Variable Frequency Drives	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Impact on environment																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Impact on environment																	

4- Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new religion** in terms of **Comfort ability for users**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
	Criterion: Comfort ability for users																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
	Criterion: Comfort ability for users																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
	Criterion: Comfort ability for users																	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
Variable Frequency Drives	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
Variable Frequency Drives	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	

5- Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new religion** in terms of **Capital Cost**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
									Criterion: Capital Cost									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
									Criterion: Capital Cost									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
									Criterion: Capital Cost									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
									Criterion: Capital Cost									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Capital Cost									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
									Criterion: Capital Cost									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
									Criterion: Capital Cost									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
									Criterion: Capital Cost									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Capital Cost									

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Variable Frequency Drives
									Criterion: Capital Cost									
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
									Criterion: Capital Cost									
Building Management Systems (BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Capital Cost									
Variable Frequency Drives	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
									Criterion: Capital Cost									
Variable Frequency Drives	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Capital Cost									
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Capital Cost									

AHP questionnaire

1- Existing School building - This section of questionnaire is composed of two parts:

IV- Pair-wise comparison for decision Criteria of existing School building.
V- Pair-wise comparison for decision alternatives of existing School building.

School building

III- **Pair-wise comparison for decision Criteria of existing school buildings**.

#	**Decision Criteria:**
1	Reduction in consumption
2	Ease of implementation
3	Impact on environment (CO_2, SO_x, NO_x)
4	Comfort ability for users.
5	Capital cost

1-Indicate below the level of importance for each two corresponding criteria in terms of selecting the best demand side management technologies in **Existing School building.**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Ease of implementation
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Impact on environment
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Impact on environment
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Impact on environment	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Impact on environment	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Comfort ability for users	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost

II - Pair-wise comparison for decision alternatives of existing school building.

#	Decision alternatives:
1	High Efficiency Lighting
2	Programmable Thermostats
3	Time of use control – lighting
4	Variable Frequency Drives (VFD)
5	Power Factor Correction.
6	Remote control for A/C Units

1-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing school** in terms of **reduction in consumption**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Reduction in consumption																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Reduction in consumption																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Reduction in consumption																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Reduction in consumption																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Reduction in consumption																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Reduction in consumption																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Reduction in consumption																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Reduction in consumption																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Reduction in consumption																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Reduction in consumption																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Reduction in consumption																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Reduction in consumption																	

2-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing school** in terms of **ease of implementation**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Ease of implementation																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Ease of implementation																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Ease of implementation																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Ease of implementation																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Ease of implementation																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Ease of implementation																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Ease of implementation																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Ease of implementation																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Ease of implementation																	

3-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing school** in terms of **Impact on environment**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
									Criterion: Impact on environment									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
									Criterion: Impact on environment									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Impact on environment									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
									Criterion: Impact on environment									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
									Criterion: Impact on environment									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
									Criterion: Impact on environment									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Impact on environment									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
									Criterion: Impact on environment									
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
									Criterion: Impact on environment									

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Impact on environment																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Impact on environment																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Impact on environment																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Impact on environment																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Impact on environment																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Impact on environment																	

4-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing school** in terms of **Comfort ability for users**.

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Comfort ability for users																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Comfort ability for users																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Comfort ability for users																	

5-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **existing school** in terms of **Capital Cost**.

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐ Criterion: Capital Cost	☐	☐	☐	☐	☐	☐	☐	☐	Programmable Thermostats
High Efficiency Lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐ Criterion: Capital Cost	☐	☐	☐	☐	☐	☐	☐	☐	VFD
High Efficiency Lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐ Criterion: Capital Cost	☐	☐	☐	☐	☐	☐	☐	☐	Remote control for A/C Units
High Efficiency Lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐ Criterion: Capital Cost	☐	☐	☐	☐	☐	☐	☐	☐	TOU control - lighting
High Efficiency Lighting	☐	☐	☐	☐	☐	☐	☐	☐	☐ Criterion: Capital Cost	☐	☐	☐	☐	☐	☐	☐	☐	P. F Correction.
Programmable Thermostats	☐	☐	☐	☐	☐	☐	☐	☐	☐ Criterion: Capital Cost	☐	☐	☐	☐	☐	☐	☐	☐	VFD
Programmable Thermostats	☐	☐	☐	☐	☐	☐	☐	☐	☐ Criterion: Capital Cost	☐	☐	☐	☐	☐	☐	☐	☐	Remote control for A/C Units
Programmable Thermostats	☐	☐	☐	☐	☐	☐	☐	☐	☐ Criterion: Capital Cost	☐	☐	☐	☐	☐	☐	☐	☐	TOU control - lighting
Programmable Thermostats	☐	☐	☐	☐	☐	☐	☐	☐	☐ Criterion: Capital Cost	☐	☐	☐	☐	☐	☐	☐	☐	P. F Correction.

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Capital Cost																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Capital Cost																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	TOU control - lighting
	Criterion: Capital Cost																	
Remote control for A/C Units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	
TOU control – lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	P. F Correction.
	Criterion: Capital Cost																	

I- **Pair-wise comparison for decision Criteria of new school buildings**.

#	**Decision Criteria:**
1	Reduction in consumption
2	Ease of implementation
3	Impact on environment (CO2, SOx, NOx)
4	Comfort ability for users.
5	Capital cost

1-Indicate below the level of importance for each two corresponding criteria in terms of selecting the best demand side management technologies in **new School building.**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Ease of implementation
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Impact on environment
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Reduction in consumption	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Impact on environment
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Ease of implementation	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Impact on environment	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Comfort ability for users
Impact on environment	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost
Comfort ability for users	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Capital cost

II-**Pair-wise comparison for decision alternatives for new school building**

#	Decision alternatives:
1	Install High Efficiency Lighting
2	Install High efficient A/C units
3	Install Building Management Systems (BMS)
4	Install Variable Frequency Drives (VFD)
5	Install Programmable Thermostats
6	Install Remote control for A/C Units

1- Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new school** in terms of **reduction in consumption**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
	Criterion: Reduction in consumption																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
	Criterion: Reduction in consumption																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Reduction in consumption																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Reduction in consumption																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Building Management Systems (BMS)
	Criterion: Reduction in consumption																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Reduction in consumption																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Reduction in consumption																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	

2- Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new school** in terms of **reduction in consumption**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Reduction in consumption																	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Reduction in consumption																	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Reduction in consumption																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Reduction in consumption																	

3-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new school** in terms of **ease of implementation**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	(BMS)
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Ease of implementation																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	(BMS)
	Criterion: Ease of implementation																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Ease of implementation																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Ease of implementation																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Ease of implementation																	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Ease of implementation																	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Ease of implementation																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Ease of implementation																	

4-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new school** in terms of **Impact on environment**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
	Criterion: Impact on environment																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	(BMS)
	Criterion: Impact on environment																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Impact on environment																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Impact on environment																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Impact on environment																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	(BMS)
	Criterion: Impact on environment																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Impact on environment																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Impact on environment																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Impact on environment																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Impact on environment																	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Impact on environment																	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Impact on environment																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Impact on environment																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Impact on environment																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Impact on environment																	

5-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new school** in terms of **Comfort ability for users**

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	(BMS)
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Comfort ability for users																	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	(BMS)
	Criterion: Comfort ability for users																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Comfort ability for users																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Comfort ability for users																	
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Comfort ability for users																	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Comfort ability for users																	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Comfort ability for users																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Comfort ability for users																	

6-Indicate below the level of importance for each two corresponding DSM alternatives that suitable for **new school** in terms of **Capital cost**

	Extremely	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	High efficient A/C units
									Criterion: Capital Cost									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	(BMS)
									Criterion: Capital Cost									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
									Criterion: Capital Cost									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
									Criterion: Capital Cost									
High Efficiency Lighting	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Capital Cost									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	(BMS)
									Criterion: Capital Cost									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
									Criterion: Capital Cost									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
									Criterion: Capital Cost									
High efficient A/C units	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
									Criterion: Capital Cost									

	Extremely		Very strongly		Strongly		Moderately		Equally important		Moderately		Strongly		Very Strongly		Extremely	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	VFD
	Criterion: Capital Cost																	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Capital Cost																	
(BMS)	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Capital Cost																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Programmable Thermostats
	Criterion: Capital Cost																	
VFD	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Capital Cost																	
Programmable Thermostats	9 ☐	8 ☐	7 ☐	6 ☐	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Remote control for A/C Units
	Criterion: Capital Cost																	

AHP results:

Combination the judgments of all eight participants by using the geometric mean

New Office Building - Academics

GM = Geometric mean

Numbers 1 to 8= the Participants in filling the questionnaire

Among Objectives	1	2	3	4	5	6	7	8	GM	NGM
Reduction	0.476261	0.161907	0.284641	0.327621	0.407114	0.441412	0.427405	0.200883	0.320362	0.362631384
Implement	0.187915	0.300346	0.284641	0.110581	0.091685	0.193569	0.113187	0.455208	0.188946	0.213876296
Impact	0.174645	0.111968	0.110567	0.338424	0.138534	0.193569	0.198956	0.172926	0.169304	0.191642944
Comfort	0.052895	0.359832	0.05904	0.04619	0.308767	0.052852	0.061496	0.116699	0.093967	0.106365681
Cost	0.108285	0.065947	0.261112	0.177183	0.0539	0.118597	0.198956	0.054284	0.110857	0.125483695
1) Reduction Criteria										
H.E.L	0.1083	0.200499	0.07381	0.145114	0.391706	0.097002	0.049582	0.219231	0.132683	0.141643714
H.E.AC	0.236828	0.137845	0.292857	0.260278	0.151668	0.219795	0.231693	0.138329	0.200947	0.21451748
BMS	0.430668	0.459256	0.292857	0.406479	0.269369	0.407848	0.356571	0.450393	0.377841	0.403357746
TES	0.050487	0.035674	0.097619	0.042553	0.048858	0.065434	0.169193	0.08601	0.065722	0.070159989
PGT	0.050487	0.083363	0.121429	0.084091	0.085104	0.169285	0.09648	0.043935	0.084602	0.090315188
RC	0.123231	0.083363	0.121429	0.061485	0.053295	0.040636	0.09648	0.062102	0.074945	0.080005883
2) Ease Implementation										
H.E.L	0.161912	0.113682	0.343622	0.251553	0.104905	0.159449	0.298718	0.090625	0.170687	0.184965799
H.E.AC	0.464589	0.331938	0.343622	0.392336	0.420623	0.412942	0.298718	0.286374	0.364108	0.394567018
BMS	0.062315	0.087294	0.087411	0.09101	0.069113	0.064643	0.046154	0.109858	0.074803	0.081060713
TES	0.083336	0.103642	0.042776	0.044293	0.038886	0.032492	0.135684	0.086058	0.062784	0.068036
PGT	0.053982	0.322089	0.139793	0.150881	0.201485	0.268106	0.135684	0.390812	0.178926	0.193894003
RC	0.173866	0.041356	0.042776	0.069927	0.164987	0.062369	0.085043	0.036273	0.071496	0.077476467

3) IE										
H.E.L	0.119609	0.200499	0.07381	0.145114	0.453995	0.101859	0.049582	0.358646	0.146417	0.159966828
H.E.AC	0.230611	0.137845	0.292857	0.260278	0.1332	0.163911	0.231693	0.16079	0.193567	0.211479406
BMS	0.425011	0.459256	0.292857	0.406479	0.235389	0.386348	0.356571	0.239063	0.340366	0.371863318
TES	0.064358	0.035674	0.097619	0.042553	0.06598	0.059333	0.169193	0.111814	0.0718	0.07844438
PGT	0.041023	0.083363	0.121429	0.084091	0.06598	0.237931	0.09648	0.072926	0.088773	0.096988139
RC	0.119389	0.083363	0.121429	0.061485	0.045457	0.050618	0.09648	0.056762	0.074375	0.081257928
4) CA										
H.E.L	0.315236	0.416999	0.409524	0.265389	0.45505	0.413388	0.41019	0.173341	0.34289	0.372599361
H.E.AC	0.319898	0.18837	0.206626	0.422799	0.138622	0.138936	0.231419	0.159515	0.209724	0.227895711
BMS	0.130338	0.106826	0.089386	0.065946	0.101195	0.112785	0.091685	0.389051	0.116276	0.1263505
TES	0.063433	0.069326	0.071481	0.058289	0.050669	0.052763	0.073563	0.066248	0.062696	0.068127795
PGT	0.036103	0.158958	0.167665	0.134121	0.203795	0.226677	0.153233	0.051068	0.121229	0.131733256
RC	0.134993	0.059522	0.055317	0.053456	0.050669	0.055451	0.039911	0.160777	0.067449	0.073293377
5) Capital Cost										
H.E.L	0.133938	0.097244	0.359703	0.14966	0.104441	0.109077	0.339051	0.110168	0.152877	0.165829881
H.E.AC	0.453076	0.397071	0.166085	0.408174	0.468128	0.407507	0.163374	0.386959	0.331852	0.359969539
BMS	0.083472	0.047386	0.100668	0.077746	0.070468	0.081141	0.054468	0.07469	0.071974	0.078072005
TES	0.046035	0.047386	0.059827	0.088857	0.033639	0.039454	0.075836	0.046302	0.052071	0.056482348
PGT	0.237055	0.205456	0.264111	0.21363	0.288442	0.323368	0.304863	0.157012	0.243277	0.263889554
RC	0.046425	0.205456	0.049606	0.061933	0.034883	0.039454	0.062409	0.224868	0.069839	0.075756672

The overall priority For AHP all Academic Experts

	RC	EI	D&R	F.O&M	CC		AHP Result
H.E.L	0.141644	0.184966	0.159967	0.372599	0.16583	0.362631	0.182022
H.E.AC	0.214517	0.394567	0.211479	0.227896	0.35997	0.213876	0.272118
BMS	0.403358	0.081061	0.371863	0.12635	0.078072	0.191643	0.258108
TES	0.07016	0.068036	0.078444	0.068128	0.056482	0.106366	0.069361
PGT	0.090315	0.193894	0.096988	0.131733	0.26389	0.125484	0.139933
RC	0.080006	0.077476	0.081258	0.073293	0.075757		0.078458

Combination the judgments of all eight participants by using the geometric mean

Existing Office Building - Academics

GM = Geometric mean

Numbers 1 to 8= the Participants in filling the questionnaire

Among Objectives	1	2	3	4	5	6	7	8	GM	NGM
Reduction	0.476261	0.161907	0.284641	0.327621	0.407114	0.334133	0.456287	0.200883	0.311943	0.35453371
Implement	0.187915	0.300346	0.284641	0.110581	0.091685	0.243736	0.0991	0.455208	0.191264	0.217378112
Impact	0.174645	0.111968	0.110567	0.338424	0.138534	0.275153	0.191495	0.172926	0.17607	0.200109735
Comfort	0.052895	0.359832	0.05904	0.04619	0.308767	0.046729	0.061623	0.116699	0.092556	0.105192992
Cost	0.108285	0.065947	0.261112	0.177183	0.0539	0.10025	0.191495	0.054284	0.108035	0.122785451
1) Reduction Criteria										
H.E.L	0.169228	0.086819	0.078643	0.072676	0.439203	0.387196	0.095369	0.071923	0.133007	0.151864977
Prpg.Thermo	0.232377	0.331803	0.204054	0.222746	0.039437	0.098823	0.287416	0.354063	0.185299	0.21157017
BMS	0.4053	0.324313	0.405238	0.355231	0.144911	0.220622	0.364036	0.271228	0.296499	0.338536268
RC	0.094961	0.032952	0.165093	0.186511	0.204813	0.201126	0.146767	0.143221	0.130366	0.148849166
TOU	0.054325	0.16582	0.096764	0.120695	0.070563	0.046116	0.046439	0.035576	0.069833	0.079734227
P.F	0.043809	0.058293	0.050208	0.04214	0.101074	0.046116	0.059973	0.12399	0.060822	0.069445193
2) Ease Implementation										
H.E.L	0.179808	0.05941	0.439519	0.135417	0.398413	0.388399	0.382767	0.04427	0.18956	0.226114989
Prpg.Thermo	0.109639	0.192089	0.176396	0.400305	0.082006	0.221884	0.183839	0.31762	0.188292	0.224602771
BMS	0.033484	0.113711	0.052485	0.046474	0.056692	0.051519	0.082183	0.082701	0.060703	0.072408719
RC	0.354225	0.032476	0.052485	0.246073	0.102336	0.087273	0.050402	0.092135	0.094127	0.112278925
TOU	0.079289	0.301157	0.176396	0.125834	0.233282	0.175344	0.205578	0.344171	0.187597	0.223773961
P.F	0.243556	0.301157	0.102719	0.045897	0.127272	0.075581	0.09523	0.119103	0.118055	0.140820636

3) IE										
H.E.L	0.164761	0.086819	0.078643	0.072676	0.079563	0.352923	0.095369	0.100791	0.1104	0.120214777
Prpg.Thermo	0.229397	0.331803	0.204054	0.222746	0.209458	0.044625	0.287416	0.248839	0.197477	0.215033146
BMS	0.388598	0.324313	0.405238	0.355231	0.414087	0.187952	0.364036	0.410098	0.347122	0.377982694
RC	0.090272	0.032952	0.165093	0.186511	0.209458	0.22268	0.146767	0.133969	0.130477	0.142077174
TOU	0.090272	0.16582	0.096764	0.120695	0.043717	0.078214	0.046439	0.070962	0.081622	0.088878096
P.F	0.0367	0.058293	0.050208	0.04214	0.043717	0.113606	0.059973	0.035341	0.051257	0.055814112
4) CA										
H.E.L	0.386227	0.037425	0.396396	0.424595	0.424446	0.381984	0.465498	0.320256	0.29592	0.341653224
Prpg.Thermo	0.190064	0.399554	0.18278	0.252492	0.092565	0.224052	0.18953	0.08352	0.180973	0.208941777
BMS	0.076552	0.127583	0.076316	0.041381	0.063398	0.08001	0.042014	0.039261	0.063309	0.073093505
RC	0.172822	0.063853	0.050551	0.126606	0.253352	0.122492	0.127306	0.086274	0.111607	0.128855442
TOU	0.050787	0.243002	0.18278	0.098371	0.066313	0.154821	0.070829	0.150647	0.111743	0.129012073
P.F	0.123549	0.128583	0.111176	0.056555	0.099927	0.036641	0.104824	0.320042	0.102589	0.118443978
5) Capital Cost										
H.E.L	0.414133	0.104127	0.267923	0.187967	0.438465	0.446192	0.392994	0.043424	0.227796	0.26029241
Prpg.Thermo	0.118158	0.270154	0.292882	0.356636	0.091318	0.182962	0.225034	0.412698	0.218385	0.249539146
BMS	0.047884	0.033615	0.08716	0.043778	0.043028	0.040645	0.07561	0.049211	0.050143	0.057296337
RC	0.207671	0.033615	0.054019	0.052864	0.186234	0.069547	0.049845	0.096799	0.077078	0.088073738
TOU	0.081228	0.270154	0.149008	0.250076	0.160007	0.158195	0.131256	0.249674	0.169406	0.193572221
P.F	0.130927	0.288336	0.149008	0.108679	0.080948	0.10246	0.125261	0.148194	0.132346	0.151226149

The overall priority For AHP all Academic Experts

	RC	EI	D&R	F.O&M	CC		AHP Result
H.E.L	0.151865	0.226115	0.120215	0.341653	0.260292	0.354534	0.194949
Prpg.Thermo	0.21157	0.224603	0.215033	0.208942	0.249539	0.217378	0.219482
BMS	0.338536	0.072409	0.377983	0.073094	0.057296	0.20011	0.226125
RC	0.148849	0.112279	0.142077	0.128855	0.088074	0.105193	0.129979
TOU	0.079734	0.223774	0.088878	0.129012	0.193572	0.122785	0.132036
P.F	0.069445	0.140821	0.055814	0.118444	0.151226		0.097429

Combination the judgments of all eight participants by using the geometric mean

Existing School Building - Academics

GM = Geometric mean

Numbers 1 to 8= the Participants in filling the questionnaire

Among Objectives	1	2	3	4	5	6	7	8	GM	NGM
Reduction	0.341638	0.509602	0.267855	0.33924	0.20867	0.216194	0.132836	0.086291	0.231259	0.282223482
Implement	0.251795	0.138844	0.267855	0.150195	0.155336	0.202401	0.395174	0.086291	0.187196	0.228449725
Impact	0.117845	0.073867	0.267855	0.33924	0.06299	0.057032	0.132836	0.086291	0.115906	0.141449032
Comfort	0.068415	0.138844	0.076382	0.055325	0.510014	0.467342	0.062901	0.21443	0.137671	0.168011301
Cost	0.220306	0.138844	0.120054	0.116	0.06299	0.057032	0.276254	0.526696	0.147386	0.17986646
1) Reduction Criteria										
H.E.L	0.234779	0.209265	0.076891	0.200691	0.243329	0.228252	0.166534	0.190246	0.184352	0.192533669
Prpg.Thermo	0.489815	0.425164	0.357178	0.465798	0.45268	0.4301	0.391414	0.492264	0.435746	0.45508431
VFD	0.056863	0.144682	0.132948	0.103802	0.092244	0.09414	0.195946	0.119003	0.110967	0.115891268
RC	0.038957	0.056817	0.203124	0.095158	0.117228	0.044646	0.11031	0.103417	0.084316	0.088057748
TOU	0.119116	0.056817	0.11493	0.071064	0.056385	0.11914	0.037179	0.06253	0.073623	0.076890885
P.F	0.06047	0.107255	0.11493	0.063488	0.038135	0.083723	0.098618	0.03254	0.068502	0.071542121
2) Ease Implementation										
H.E.L	0.32942	0.050465	0.377287	0.416132	0.429186	0.414081	0.383308	0.086788	0.25035	0.277439508
Prpg.Thermo	0.32942	0.395159	0.236831	0.215542	0.254569	0.243178	0.23602	0.382516	0.279401	0.309633543
VFD	0.058225	0.145181	0.079363	0.074223	0.103065	0.096053	0.155745	0.24099	0.107994	0.119680086
RC	0.052951	0.059269	0.050928	0.040704	0.064495	0.036562	0.065124	0.056807	0.05239	0.058059075
TOU	0.140606	0.112071	0.158107	0.161053	0.107501	0.146462	0.110606	0.199416	0.138999	0.15403944
P.F	0.089377	0.237855	0.097484	0.092345	0.041183	0.063664	0.049197	0.033484	0.073225	0.081148349

3) IE										
H.E.L	0.208679	0.209265	0.076891	0.200691	0.244791	0.241982	0.166534	0.249075	0.189397	0.197369065
Prpg.Thermo	0.471037	0.425164	0.357178	0.465798	0.402075	0.451239	0.391414	0.488863	0.429441	0.447517143
VFD	0.065025	0.144682	0.132948	0.103802	0.121827	0.1296	0.195946	0.091561	0.117678	0.122631649
RC	0.092109	0.056817	0.203124	0.095158	0.131884	0.033283	0.11031	0.084163	0.089514	0.09328186
TOU	0.115918	0.056817	0.11493	0.071064	0.060955	0.060817	0.037179	0.050192	0.066273	0.069062046
P.F	0.047233	0.107255	0.11493	0.063488	0.038467	0.083079	0.098618	0.036147	0.067305	0.070138238
4) CA										
H.E.L	0.414686	0.327203	0.377945	0.436118	0.451061	0.416605	0.419797	0.092543	0.336213	0.360478483
Prpg.Thermo	0.188712	0.345721	0.217819	0.217061	0.202086	0.231925	0.245486	0.415229	0.248914	0.266879323
VFD	0.079271	0.100735	0.139082	0.064657	0.136913	0.136703	0.083083	0.240712	0.113156	0.121322616
RC	0.075428	0.058208	0.048992	0.041442	0.066766	0.03456	0.038938	0.070847	0.052389	0.056169915
TOU	0.203205	0.09681	0.090197	0.154089	0.043689	0.111816	0.098787	0.143267	0.108285	0.116100129
P.F	0.038699	0.071323	0.125965	0.086634	0.099486	0.068391	0.113909	0.037402	0.073728	0.079049533
5) Capital Cost										
H.E.L	0.412556	0.513269	0.257262	0.215912	0.45039	0.464981	0.250484	0.045918	0.270105	0.301517463
Prpg.Thermo	0.188123	0.108421	0.45405	0.394785	0.245869	0.206962	0.358447	0.45299	0.27228	0.303944877
VFD	0.155355	0.108421	0.064592	0.063167	0.124591	0.145718	0.086971	0.176668	0.108475	0.121090051
RC	0.07219	0.053048	0.035929	0.034029	0.032624	0.030559	0.045106	0.04817	0.042244	0.047156973
TOU	0.127012	0.108421	0.123576	0.202134	0.080353	0.08495	0.122739	0.161977	0.121239	0.135338197
P.F	0.044764	0.108421	0.064592	0.089973	0.066173	0.066829	0.136253	0.114277	0.081477	0.090952439

The overall priority For AHP all Academic Experts

	RC	EI	D&R	F.O&M	CC		AHP Result
H.E.L	0.192534	0.27744	0.197369	0.360478	0.301517	0.282223	0.260434
Prpg.Thermo	0.455084	0.309634	0.447517	0.266879	0.303945	0.22845	0.36198
VFD	0.115891	0.11968	0.122632	0.121323	0.12109	0.141449	0.119558
RC	0.088058	0.058059	0.093282	0.05617	0.047157	0.168011	0.069229
TOU	0.076891	0.154039	0.069062	0.1161	0.135338	0.179866	0.110508
P.F	0.071542	0.081148	0.070138	0.07905	0.090952		0.078291

Combination the judgments of all eight participants by using the geometric mean

New School Building - Academics

GM = Geometric mean

Numbers 1 to 8= the Participants in filling the questionnaire

Among Objectives	1	2	3	4	5	6	7	8	GM	NGM
Reduction	0.341638	0.509602	0.267855	0.33924	0.20867	0.265164	0.132836	0.086291	0.237237	0.289163321
Implement	0.251795	0.138844	0.267855	0.150195	0.155336	0.154577	0.395174	0.086291	0.180993	0.22060908
Impact	0.117845	0.073867	0.267855	0.33924	0.06299	0.061231	0.132836	0.086291	0.11694	0.142535586
Comfort	0.068415	0.138844	0.076382	0.055325	0.510014	0.460594	0.062901	0.21443	0.137421	0.16750017
Cost	0.220306	0.138844	0.120054	0.116	0.06299	0.058434	0.276254	0.526696	0.147834	0.180191843
1) Reduction Criteria										
H.E.L	0.064168	0.039744	0.061025	0.092986	0.157572	0.108624	0.04004	0.064838	0.070963	0.077595296
H.E.AC	0.435815	0.425064	0.227727	0.269525	0.211288	0.369366	0.154388	0.41642	0.294802	0.322356515
BMS	0.259603	0.22625	0.371885	0.409119	0.198467	0.253234	0.412115	0.230905	0.28435	0.310926654
VFD	0.038102	0.138102	0.067748	0.090351	0.331571	0.035626	0.080442	0.032899	0.075054	0.08206888
PGT	0.101155	0.100675	0.165227	0.061185	0.066513	0.058021	0.080442	0.149128	0.091153	0.099672772
RC	0.101155	0.070164	0.106389	0.076834	0.034589	0.17513	0.232574	0.105809	0.098201	0.107379884
2) Ease Implementation										
H.E.L	0.337707	0.03967	0.36433	0.397638	0.42567	0.402337	0.254652	0.463083	0.281291	0.320241711
H.E.AC	0.243541	0.42421	0.211694	0.212795	0.07247	0.239806	0.279706	0.032337	0.171014	0.194693931
BMS	0.080227	0.238828	0.13305	0.073855	0.072613	0.112103	0.071482	0.06895	0.096554	0.109923966
VFD	0.08804	0.087003	0.070696	0.137443	0.189901	0.054627	0.129319	0.156265	0.105718	0.120356543
PGT	0.212675	0.133213	0.179514	0.132392	0.197477	0.148756	0.178721	0.221384	0.172462	0.196342312
RC	0.037809	0.077077	0.040715	0.045877	0.041869	0.042371	0.08612	0.057979	0.051333	0.058441537

3) IE										
H.E.L	0.064168	0.039744	0.061025	0.092986	0.064648	0.112992	0.04004	0.075958	0.065073	0.069584798
H.E.AC	0.435815	0.425064	0.227727	0.269525	0.258095	0.381376	0.154388	0.425552	0.304305	0.325405926
BMS	0.259603	0.22625	0.371885	0.409119	0.409337	0.192608	0.412115	0.203946	0.29618	0.316717729
VFD	0.038102	0.138102	0.067748	0.090351	0.069073	0.040513	0.080442	0.043235	0.064867	0.069365257
PGT	0.101155	0.100675	0.165227	0.061185	0.164741	0.077535	0.080442	0.150746	0.106006	0.113357163
RC	0.101155	0.070164	0.106389	0.076834	0.034106	0.194977	0.232574	0.100562	0.098723	0.105569126
4) CA										
H.E.L	0.416576	0.150154	0.414439	0.440597	0.385332	0.445671	0.366003	0.417036	0.362685	0.392522631
H.E.AC	0.190629	0.05736	0.209575	0.192255	0.199205	0.097631	0.190414	0.064309	0.134155	0.145192038
BMS	0.089629	0.358108	0.068458	0.096814	0.109227	0.066473	0.05063	0.100676	0.097055	0.105039277
VFD	0.074325	0.07827	0.068458	0.077271	0.080333	0.128839	0.104188	0.144897	0.091253	0.098760521
PGT	0.187526	0.32301	0.170614	0.150168	0.186246	0.223397	0.104188	0.235042	0.18831	0.203802206
RC	0.041315	0.033099	0.068458	0.042895	0.039658	0.03799	0.184577	0.03804	0.050527	0.054683327
5) Capital Cost										
H.E.L	0.414513	0.491124	0.256235	0.381477	0.441296	0.428868	0.284992	0.441845	0.384148	0.4025363
H.E.AC	0.087246	0.066254	0.256235	0.115812	0.118853	0.07894	0.284992	0.077075	0.117098	0.122703355
BMS	0.073106	0.059351	0.110036	0.073381	0.05757	0.056687	0.067614	0.040819	0.064921	0.068028508
VFD	0.195306	0.127757	0.08883	0.194564	0.118853	0.172555	0.15214	0.117564	0.141221	0.147980245
PGT	0.184437	0.127757	0.239568	0.18436	0.226908	0.232752	0.141029	0.281878	0.196079	0.205464211
RC	0.045391	0.127757	0.049096	0.050407	0.036519	0.030197	0.069232	0.040819	0.050853	0.05328738

The overall priority For AHP all Academic Experts

	RC	EI	D&R	F.O&M	CC		AHP Result
H.E.L	0.077595	0.320242	0.069585	0.392523	0.402536	0.289163	0.241286
Prpg.Thermo	0.322357	0.194694	0.325406	0.145192	0.122703	0.220609	0.228977
Maint. A/C	0.310927	0.109924	0.316718	0.105039	0.068029	0.142536	0.189155
BMS	0.082069	0.120357	0.069365	0.098761	0.14798	0.1675	0.103377
TOU	0.099673	0.196342	0.113357	0.203802	0.205464	0.180192	0.159454
P.F	0.10738	0.058442	0.105569	0.054683	0.053287		0.077752

Combination the judgments of all eight participants by using the geometric mean

New Religion Building - Academics

GM = Geometric mean

Numbers 1 to 8= the Participants in filling the questionnaire

Among Objectives	1	2	3	4	5	6	7	8	GM	NGM
Reduction	0.478791	0.475615	0.347101	0.250483	0.266548	0.198956	0.284179	0.285946	0.310013	0.35140599
Implement	0.189264	0.174669	0.133478	0.189725	0.107346	0.113187	0.26275	0.111982	0.152937	0.17335676
Impact	0.084435	0.059378	0.320434	0.250483	0.163447	0.198956	0.11777	0.285946	0.160515	0.181946488
Comfort	0.058247	0.099452	0.065509	0.135927	0.409346	0.427405	0.051121	0.248446	0.135646	0.153757602
Cost	0.189264	0.190886	0.133478	0.173382	0.053313	0.061496	0.284179	0.06768	0.123097	0.139533161
1) Reduction Criteria										
H.E.L	0.094882	0.094882	0.111686	0.104562	0.175679	0.081787	0.078303	0.092162	0.101084	0.105966816
H.E.AC	0.322698	0.322698	0.24243	0.239338	0.374818	0.24082	0.327084	0.318642	0.294668	0.308900831
BMS	0.322698	0.322698	0.422803	0.454753	0.23942	0.438765	0.173606	0.318642	0.322271	0.337836422
VFD	0.146649	0.068075	0.044159	0.089057	0.082437	0.056973	0.052538	0.066888	0.071031	0.074461527
TOC	0.044998	0.044998	0.111686	0.056145	0.043886	0.038111	0.151384	0.048492	0.059443	0.06231445
RC	0.068075	0.146649	0.067236	0.056145	0.08376	0.143543	0.217085	0.155173	0.105428	0.110519954
2) Ease Implementation										
H.E.L	0.376715	0.376715	0.219932	0.391225	0.399598	0.469789	0.397693	0.405234	0.37234	0.400229948
H.E.AC	0.140675	0.140675	0.258394	0.205422	0.094861	0.051189	0.1938	0.063297	0.125761	0.135180611
BMS	0.039078	0.039078	0.241727	0.073257	0.061636	0.051189	0.047798	0.060779	0.062991	0.067708745
VFD	0.250404	0.250404	0.084422	0.169846	0.162599	0.11618	0.066012	0.177338	0.145314	0.156198699
TOC	0.11323	0.11323	0.146752	0.12187	0.242054	0.134699	0.172526	0.226452	0.152471	0.163891991
RC	0.079898	0.079898	0.048773	0.03838	0.039252	0.176955	0.12217	0.066901	0.071439	0.076790007

3) IE										
H.E.L	0.094882	0.094882	0.111686	0.104562	0.403772	0.152127	0.078303	0.092162	0.121214	0.133567158
H.E.AC	0.322698	0.322698	0.24243	0.239338	0.227059	0.380772	0.327084	0.318642	0.293086	0.322955697
BMS	0.322698	0.322698	0.422803	0.454753	0.070252	0.248779	0.173606	0.318642	0.257547	0.28379493
VFD	0.146649	0.146649	0.044159	0.089057	0.163319	0.052322	0.052538	0.066888	0.084256	0.092842622
TOC	0.044998	0.044998	0.111686	0.056145	0.101263	0.046667	0.151384	0.048492	0.067684	0.074582323
RC	0.068075	0.068075	0.067236	0.056145	0.034334	0.119333	0.217085	0.155173	0.083724	0.09225727
4) CA										
H.E.L	0.368541	0.368541	0.385102	0.380685	0.391679	0.412812	0.381477	0.426998	0.38901	0.404467232
H.E.AC	0.129163	0.129163	0.158257	0.233529	0.119086	0.113498	0.195048	0.104754	0.142526	0.148188722
BMS	0.072928	0.072928	0.158257	0.068885	0.046613	0.048237	0.076024	0.053319	0.069243	0.071993885
VFD	0.258761	0.258761	0.125063	0.169789	0.164856	0.134539	0.050259	0.147384	0.148271	0.154162415
TOC	0.129163	0.129163	0.123169	0.110526	0.237716	0.243346	0.173774	0.212003	0.162408	0.168860633
RC	0.041444	0.041444	0.050153	0.036586	0.04005	0.047568	0.123418	0.055541	0.050327	0.052327112
5) Capital Cost										
H.E.L	0.394497	0.394497	0.345698	0.425881	0.466251	0.432445	0.393428	0.474422	0.413959	0.431514217
H.E.AC	0.196291	0.196291	0.15232	0.115956	0.087148	0.170603	0.168028	0.062469	0.134359	0.140057396
BMS	0.073321	0.073321	0.104389	0.0676	0.052067	0.126953	0.050408	0.046061	0.070087	0.073059225
VFD	0.196291	0.196291	0.073878	0.22655	0.175097	0.116895	0.074362	0.184736	0.14365	0.149742386
TOC	0.102126	0.102126	0.282492	0.126638	0.178905	0.113777	0.197771	0.177128	0.150703	0.157093938
RC	0.037475	0.037475	0.041224	0.037375	0.040532	0.039327	0.116003	0.055184	0.046558	0.048532838

The overall priority For AHP all Academic Experts

	RC	EI	D&R	F.O&M	CC		AHP Result
H.E.L	0.105967	0.40023	0.133567	0.404467	0.431514	0.351406	0.253322
H.E.AC	0.308901	0.135181	0.322956	0.148189	0.140057	0.173357	0.233073
BMS	0.337836	0.067709	0.283795	0.071994	0.073059	0.181946	0.203355
VFD	0.074462	0.156199	0.092843	0.154162	0.149742	0.153758	0.114734
TOC	0.062314	0.163892	0.074582	0.168861	0.157094	0.139533	0.111763
RC	0.11052	0.07679	0.092257	0.052327	0.048533		0.083753

Combination the judgments of all eight participants by using the geometric mean

Existing Religion Building - Academics

GM = Geometric mean

Numbers 1 to 8= the Participants in filling the questionnaire

Among Objectives	1	2	3	4	5	6	7	8	GM	NGM
Reduction	0.478791	0.475615	0.347101	0.250483	0.198956	0.21863	0.284179	0.285946	0.302428	0.343833326
Implement	0.189264	0.174669	0.133478	0.189725	0.113187	0.108765	0.26275	0.111982	0.153188	0.174160853
Impact	0.084435	0.059378	0.320434	0.250483	0.198956	0.1951	0.11777	0.285946	0.164106	0.18657385
Comfort	0.058247	0.099452	0.065509	0.135927	0.427405	0.422113	0.051121	0.248446	0.136168	0.154810702
Cost	0.189264	0.190886	0.133478	0.173382	0.061496	0.055392	0.284179	0.06768	0.123687	0.140621268
1) Reduction Criteria										
H.E.L	0.089782	0.066618	0.133631	0.24156	0.429289	0.156027	0.157086	0.420201	0.174344	0.199585785
Prpg.Thermo	0.206845	0.302917	0.320377	0.365686	0.229842	0.39885	0.333021	0.167463	0.279767	0.320272116
VFD	0.060615	0.302917	0.053239	0.040179	0.059845	0.082334	0.03445	0.0384	0.063246	0.07240291
RC	0.179067	0.039611	0.280119	0.163375	0.085978	0.235728	0.333021	0.072619	0.141322	0.161783346
TOU	0.206845	0.136381	0.133631	0.083997	0.042407	0.044727	0.071211	0.109303	0.090932	0.10409791
P.F	0.256845	0.151555	0.079004	0.105203	0.15264	0.082334	0.071211	0.192013	0.123917	0.141857933
2) Ease Implementation										
H.E.L	0.426035	0.062403	0.303737	0.384045	0.438091	0.38563	0.365611	0.408891	0.306716	0.335429099
Prpg.Thermo	0.126448	0.30217	0.234094	0.235627	0.206924	0.239315	0.159216	0.136015	0.19691	0.215342875
VFD	0.190515	0.141432	0.071858	0.070661	0.112391	0.153054	0.050587	0.169553	0.109177	0.119397652
RC	0.030418	0.033152	0.063525	0.039925	0.042399	0.031464	0.08621	0.03317	0.04204	0.04597537
TOU	0.07545	0.319411	0.234094	0.112302	0.130532	0.113417	0.140698	0.185862	0.149179	0.163144076
P.F	0.151133	0.141432	0.092692	0.157441	0.069662	0.07712	0.197678	0.066509	0.110378	0.120710927

3) IE										
H.E.L	0.089782	0.066618	0.137148	0.24156	0.256738	0.158233	0.157086	0.420201	0.164313	0.185324115
Prpg.Thermo	0.206845	0.302917	0.324408	0.365686	0.347339	0.416611	0.333021	0.167463	0.296658	0.334591982
VFD	0.060615	0.302917	0.053325	0.040179	0.065022	0.047625	0.03445	0.0384	0.059691	0.067323532
RC	0.179067	0.039611	0.280889	0.163375	0.110469	0.238693	0.333021	0.072619	0.146098	0.164780216
TOU	0.206845	0.136381	0.112148	0.083997	0.045541	0.039157	0.071211	0.109303	0.088279	0.099566997
P.F	0.256845	0.151555	0.092081	0.105203	0.174891	0.099681	0.071211	0.192013	0.131587	0.148413158
4) CA										
H.E.L	0.441021	0.271573	0.329843	0.402301	0.396912	0.458402	0.298718	0.337381	0.361465	0.386971493
Prpg.Thermo	0.07795	0.432064	0.329843	0.202292	0.246301	0.161206	0.298718	0.309289	0.231481	0.247815631
VFD	0.176475	0.055837	0.066415	0.163331	0.149144	0.048284	0.046154	0.153335	0.092688	0.09922869
RC	0.045704	0.055837	0.081674	0.050012	0.060118	0.078279	0.085043	0.05748	0.06273	0.067157085
TOU	0.082375	0.056656	0.131385	0.106288	0.116295	0.108056	0.135684	0.104661	0.101906	0.109096883
P.F	0.176475	0.128034	0.06084	0.075777	0.031229	0.145774	0.135684	0.037853	0.083816	0.089730219
5) Capital Cost										
H.E.L	0.346687	0.058351	0.302423	0.407252	0.328941	0.366741	0.392281	0.383613	0.286371	0.313060316
Prpg.Thermo	0.075684	0.30928	0.311081	0.229656	0.33613	0.254655	0.202016	0.229189	0.225252	0.246244983
VFD	0.176451	0.30928	0.110742	0.070697	0.096607	0.099695	0.059019	0.161907	0.118667	0.129726306
RC	0.044067	0.028047	0.042292	0.039715	0.035448	0.04081	0.059019	0.038179	0.04016	0.0439032
TOU	0.125531	0.147521	0.166611	0.15147	0.1374	0.169944	0.143832	0.11951	0.144261	0.157705756
P.F	0.23158	0.147521	0.066852	0.101208	0.065474	0.068154	0.143832	0.067602	0.100036	0.109359438

The overall priority For AHP all Academic Experts

	RC	EI	D&R	F.O&M	CC		AHP Result
H.E.L	0.199586	0.335429	0.185324	0.386971	0.31306	0.343833	0.26555
Prpg.Thermo	0.320272	0.215343	0.334592	0.247816	0.246245	0.174161	0.283042
VFD	0.072403	0.119398	0.067324	0.099229	0.129726	0.186574	0.091854
RC	0.161783	0.045975	0.16478	0.067157	0.043903	0.154811	0.110948
TOU	0.104098	0.163144	0.099567	0.109097	0.157706	0.140621	0.121848
P.F	0.141858	0.120711	0.148413	0.08973	0.109359		0.126758

FAHP results:

Combination the judgments of all eight participants by using the geometric mean

New Office Building - Academics

GM = Geometric mean

Numbers 1 to 8= the Participants in filling the questionnaire

Among Objectives	1	2	3	4	5	6	7	8	GM	NGM
Reduction	0.441662	0.194057	0.287063	0.3227	0.359309	0.405226	0.384271596	0.227664	0.316674	0.351228
Implement	0.195652	0.315336	0.287063	0.124562	0.113428	0.199895	0.130348018	0.437438	0.202719	0.224839
Impact	0.19185	0.131576	0.134242	0.300415	0.153093	0.199895	0.213763213	0.160209	0.179273	0.198835
Comfort	0.051567	0.303855	0.055504	0.043554	0.326978	0.050153	0.05785396	0.118184	0.089849	0.099653
Cost	0.119268	0.055176	0.236127	0.208769	0.047192	0.144831	0.213763213	0.056505	0.113104	0.125446
1) Reduction Criteria										1
H.E.L	0.130037	0.219169	0.068618	0.179342	0.360495	0.118055	0.046022804	0.229199	0.141137	0.151599
H.E.AC	0.263257	0.153037	0.284632	0.276959	0.17663	0.240632	0.236190531	0.153714	0.216912	0.232991
BMS	0.379381	0.398634	0.284632	0.343058	0.259661	0.338583	0.316438019	0.401382	0.33663	0.361582
TES	0.046936	0.031655	0.092747	0.037139	0.040147	0.076095	0.189365725	0.108545	0.065069	0.069892
PGT	0.046936	0.098753	0.134686	0.098587	0.106943	0.192499	0.10599146	0.036018	0.091321	0.09809
RC	0.133454	0.098753	0.134686	0.064915	0.056125	0.034135	0.10599146	0.071143	0.079922	0.085846
2) Ease Implementation										
H.E.L	0.17663	0.133215	0.329806	0.266672	0.139949	0.188364	0.27870945	0.09882	0.187112	0.202643
H.E.AC	0.418654	0.31473	0.329806	0.337333	0.370542	0.360283	0.27870945	0.307487	0.337343	0.365344
BMS	0.058384	0.093519	0.108412	0.108084	0.076283	0.073771	0.04301	0.116508	0.08073	0.087431
TES	0.092324	0.105594	0.04103	0.037996	0.032297	0.028439	0.152150797	0.093304	0.061254	0.066338
PGT	0.048982	0.31473	0.149917	0.16651	0.19388	0.275371	0.152150797	0.348065	0.179714	0.194631
RC	0.205026	0.038211	0.04103	0.083404	0.187048	0.073771	0.095269507	0.035816	0.077205	0.083613

3) Environment Impact										
H.E.L	0.151999	0.219169	0.068618	0.179342	0.416828	0.124403	0.046022804	0.322633	0.153958	0.167801
H.E.AC	0.250853	0.153037	0.284632	0.276959	0.160043	0.19695	0.236190531	0.183465	0.212344	0.231438
BMS	0.361461	0.398634	0.284632	0.343058	0.243683	0.326906	0.316438019	0.233577	0.308874	0.336648
TES	0.074873	0.031655	0.092747	0.037139	0.068552	0.048691	0.189365725	0.135301	0.071696	0.078143
PGT	0.033638	0.098753	0.134686	0.098587	0.068552	0.255254	0.10599146	0.074765	0.09404	0.102496
RC	0.127176	0.098753	0.134686	0.064915	0.042341	0.047796	0.10599146	0.05026	0.076588	0.083474
4) Comfort ability to users										
H.E.L	0.295531	0.390014	0.368223	0.284849	0.418816	0.371291	0.366253765	0.185699	0.326094	0.351097
H.E.AC	0.281158	0.202763	0.211137	0.381306	0.160979	0.164854	0.236802251	0.166708	0.216396	0.232988
BMS	0.157103	0.115612	0.102278	0.073779	0.120593	0.125103	0.107918078	0.353558	0.129459	0.139385
TES	0.076483	0.068153	0.077945	0.064971	0.047894	0.048612	0.085785528	0.073513	0.066611	0.071718
PGT	0.031064	0.165953	0.186804	0.145689	0.203823	0.239887	0.166252892	0.049094	0.124027	0.133536
RC	0.158661	0.057504	0.053612	0.049406	0.047894	0.050254	0.036987486	0.171428	0.066199	0.071275
5) Capital Cost										
H.E.L	0.166281	0.120319	0.362012	0.177689	0.13301	0.128802	0.331898592	0.132638	0.177166	0.189979
H.E.AC	0.394479	0.33104	0.194578	0.365404	0.405773	0.343563	0.193956581	0.33649	0.30963	0.332022
BMS	0.102964	0.043931	0.121885	0.082354	0.083286	0.095827	0.050913914	0.084438	0.079262	0.084995
TES	0.040068	0.043931	0.062941	0.098318	0.030177	0.036599	0.08743073	0.040544	0.050552	0.054208
PGT	0.25614	0.230389	0.215106	0.225019	0.315847	0.35861	0.273117009	0.173784	0.250198	0.268292
RC	0.040068	0.230389	0.043478	0.051216	0.031907	0.036599	0.062683173	0.232106	0.065749	0.070504

The overall priority For FAHP all Academic Experts

	RC	EI	IE	CA	CC		FAHP Result
H.E.L	0.151599	0.202643	0.167801	0.351097	0.189979	0.351228	0.190992408
H.E.AC	0.232991	0.365344	0.231438	0.232988	0.332022	0.224839	0.274862932
BMS	0.361582	0.087431	0.336648	0.139385	0.084995	0.198835	0.238145128
TES	0.069892	0.066338	0.078143	0.071718	0.054208	0.099653	0.068948066
PGT	0.09809	0.194631	0.102496	0.133536	0.268292	0.125446	0.145555757
RC	0.085846	0.083613	0.083474	0.071275	0.070504		0.081495709

Combination the judgments of all eight participants by using the geometric mean

Existing Office Building - Academics

GM = Geometric mean

Numbers 1 to 8= the Participants in filling the questionnaire

Among Objectives	1	2	3	4	5	6	7	8	GM	NGM
Reduction	0.441662	0.194057	0.287063	0.3227	0.359309	0.289931	0.414695176	0.227664	0.306601	0.341311
Implement	0.195652	0.315336	0.287063	0.124562	0.113428	0.273676	0.120743561	0.437438	0.208831	0.232473
Impact	0.19185	0.131576	0.134242	0.300415	0.153093	0.2655	0.204580516	0.160209	0.184731	0.205645
Comfort	0.051567	0.303855	0.055504	0.043554	0.326978	0.041217	0.055400231	0.118184	0.087198	0.09707
Cost	0.119268	0.055176	0.236127	0.208769	0.047192	0.129675	0.204580516	0.056505	0.110942	0.123502
1) Reduction Criteria										
H.E.L	0.189208	0.111492	0.091863	0.085778	0.385445	0.34691	0.118362993	0.080221	0.146402	0.165489
Prpg.Thermo	0.264468	0.305439	0.20638	0.22272	0.036029	0.114414	0.295563484	0.287909	0.1838	0.207762
BMS	0.332817	0.292977	0.360259	0.307785	0.16352	0.209955	0.317363156	0.291176	0.276639	0.312704
RC	0.116035	0.026222	0.182622	0.210317	0.216208	0.241236	0.163797714	0.175738	0.143061	0.161712
TOU	0.058453	0.188639	0.115621	0.136189	0.079397	0.043742	0.041556491	0.032878	0.073195	0.082738
P.F	0.039019	0.07523	0.043255	0.037211	0.119401	0.043742	0.063356162	0.132079	0.061569	0.069596
2) Ease Implementation										
H.E.L	0.216905	0.076163	0.409849	0.157923	0.353553	0.354508	0.338040064	0.047909	0.195915	0.225604
Prpg.Thermo	0.12049	0.233802	0.181304	0.367691	0.095088	0.21821	0.192792572	0.335982	0.199647	0.2299
BMS	0.030756	0.13394	0.050379	0.042192	0.051667	0.048502	0.096947324	0.085513	0.060601	0.069785
RC	0.296015	0.027263	0.050379	0.232079	0.096053	0.082523	0.044501256	0.090733	0.086099	0.099146
TOU	0.093588	0.264415	0.181304	0.155525	0.258095	0.205978	0.225263438	0.312334	0.200483	0.230864
P.F	0.242245	0.264415	0.126785	0.04459	0.145544	0.090279	0.102455346	0.127529	0.12566	0.144702

3) Environment Impact										
H.E.L	0.195601	0.115669	0.091863	0.085778	0.103033	0.294216	0.118362993	0.110369	0.127674	0.139318
Prpg.Thermo	0.239709	0.278014	0.20638	0.22272	0.23391	0.040124	0.295563484	0.265432	0.196859	0.214812
BMS	0.341101	0.303837	0.360259	0.307785	0.350826	0.211662	0.317363156	0.346121	0.313681	0.342289
RC	0.094323	0.027187	0.182622	0.210317	0.23391	0.235141	0.163797714	0.154678	0.138736	0.151389
TOU	0.094323	0.195679	0.115621	0.136189	0.03916	0.086327	0.041556491	0.092836	0.08858	0.096659
P.F	0.034944	0.079614	0.043255	0.037211	0.03916	0.13253	0.063356162	0.030565	0.050892	0.055534
4) Comfort ability to users										
H.E.L	0.343456	0.032928	0.35073	0.38688	0.387666	0.343293	0.414163374	0.311795	0.267698	0.308203
Prpg.Thermo	0.195975	0.338714	0.190944	0.254843	0.103048	0.238868	0.19940753	0.092667	0.186588	0.214821
BMS	0.091143	0.143481	0.088806	0.038838	0.059768	0.092385	0.038470568	0.037279	0.065934	0.07591
RC	0.179561	0.07537	0.044044	0.140301	0.281464	0.119101	0.145044817	0.093566	0.118179	0.13606
TOU	0.045183	0.254875	0.190944	0.115507	0.062388	0.171163	0.079397191	0.168033	0.11744	0.13521
P.F	0.144682	0.154632	0.134532	0.063631	0.105667	0.03519	0.12351652	0.29666	0.112738	0.129796
5) Capital Cost										
H.E.L	0.383868	0.156577	0.259435	0.224307	0.403633	0.406409	0.35072978	0.042215	0.232352	0.25974
Prpg.Thermo	0.139633	0.253696	0.259435	0.320795	0.099189	0.195534	0.225829343	0.374949	0.216583	0.242112
BMS	0.047782	0.029771	0.10075	0.043474	0.040274	0.03535	0.088806294	0.046102	0.049546	0.055386
RC	0.21056	0.029771	0.04844	0.046908	0.203618	0.079359	0.044044023	0.115942	0.076519	0.085538
TOU	0.082915	0.253696	0.16597	0.239954	0.160902	0.153148	0.14618191	0.252014	0.171845	0.1921
P.F	0.135242	0.276489	0.16597	0.124562	0.092385	0.1302	0.14440865	0.168779	0.147712	0.165123

The overall priority For FAHP all Academic Experts

	RC	EI	IE	CA	CC		FAHP Result
H.E.L	0.165489	0.225604	0.139318	0.308203	0.25974	0.341311	0.199575155
Prpg.Thermo	0.207762	0.2299	0.214812	0.214821	0.242112	0.232473	0.219285899
BMS	0.312704	0.069785	0.342289	0.07591	0.055386	0.205645	0.20755129
RC	0.161712	0.099146	0.151389	0.13606	0.085538	0.09707	0.1331466
TOU	0.082738	0.230864	0.096659	0.13521	0.1921	0.123502	0.138635613
P.F	0.069596	0.144702	0.055534	0.129796	0.165123		0.101805442

Combination the judgments of all eight participants by using the geometric mean

Existing School Building - Academics

GM = Geometric mean

Numbers 1 to 8= the Participants in filling the questionnaire

Among Objectives	1	2	3	4	5	6	7	8	GM	NGM
Reduction	0.335081	0.475457	0.260412	0.322255	0.259509	0.253287	0.147977333	0.083775	0.23969	0.287008
Implement	0.247167	0.154463	0.260412	0.169511	0.176161	0.249964	0.366214598	0.083775	0.19709	0.235998
Impact	0.131778	0.061153	0.260412	0.322255	0.058302	0.052862	0.147977333	0.083775	0.112598	0.134827
Comfort	0.070951	0.154463	0.070589	0.052263	0.447727	0.391024	0.058849164	0.246937	0.133824	0.160242
Cost	0.215023	0.154463	0.148175	0.133717	0.058302	0.052862	0.278981572	0.501738	0.15193	0.181924
1) Reduction Criteria										
H.E.L	0.269486	0.035513	0.081	0.222335	0.25648	0.24568	0.179246163	0.203344	0.158376	0.170801
Prpg.Thermo	0.428354	0.367442	0.335637	0.429731	0.395009	0.380451	0.3491616	0.43283	0.388185	0.418639
VFD	0.060314	0.242476	0.130271	0.110993	0.111107	0.103631	0.212267789	0.129048	0.126769	0.136714
RC	0.034327	0.157782	0.216943	0.1057	0.139835	0.039421	0.126985211	0.131672	0.101704	0.109683
TOU	0.136019	0.11819	0.118075	0.068267	0.065455	0.136703	0.035789081	0.073548	0.086213	0.092977
P.F	0.071499	0.078598	0.118075	0.062974	0.032114	0.094115	0.096550155	0.029557	0.066009	0.071187
2) Ease Implementation										
H.E.L	0.314709	0.035721	0.344566	0.370055	0.370089	0.370167	0.342416465	0.105425	0.227155	0.249409
Prpg.Thermo	0.314709	0.369475	0.226652	0.22445	0.276411	0.250206	0.240766826	0.335005	0.275302	0.302273
VFD	0.05728	0.2579	0.091863	0.086705	0.120673	0.115114	0.169046796	0.233913	0.126271	0.138642
RC	0.048625	0.095202	0.043255	0.037368	0.075228	0.034286	0.079392451	0.068564	0.056582	0.062125
TOU	0.156085	0.156279	0.178043	0.172334	0.123	0.155998	0.127256373	0.227581	0.159358	0.17497
P.F	0.108593	0.085424	0.115621	0.109089	0.034598	0.074229	0.041121089	0.029513	0.066106	0.072582

3) Environment Impact										
H.E.L	0.234747	0.035513	0.081	0.222335	0.248723	0.267831	0.179246163	0.287032	0.163655	0.176229
Prpg.Thermo	0.427397	0.367442	0.335637	0.429731	0.342402	0.381791	0.3491616	0.418999	0.379827	0.409009
VFD	0.059148	0.242476	0.130271	0.110993	0.150688	0.153109	0.212267789	0.105991	0.134585	0.144925
RC	0.100229	0.157782	0.216943	0.1057	0.153015	0.029112	0.126985211	0.100903	0.10952	0.117934
TOU	0.132039	0.11819	0.118075	0.068267	0.072901	0.074862	0.035789081	0.054325	0.077745	0.083718
P.F	0.046441	0.078598	0.118075	0.062974	0.032271	0.093297	0.096550155	0.032751	0.063319	0.068184
4) Comfort ability to users										
H.E.L	0.364633	0.183609	0.350324	0.383179	0.409438	0.378254	0.374777311	0.123687	0.299372	0.331603
Prpg.Thermo	0.203732	0.064481	0.208102	0.241088	0.199461	0.222832	0.261761446	0.365823	0.202299	0.224079
VFD	0.090195	0.338527	0.153028	0.068769	0.157523	0.151295	0.093249659	0.245979	0.143081	0.158485
RC	0.087718	0.096269	0.045427	0.039912	0.077556	0.031458	0.036392512	0.07918	0.056754	0.062864
TOU	0.218479	0.289296	0.10377	0.165026	0.038028	0.140763	0.106807348	0.153443	0.132492	0.146756
P.F	0.035243	0.027819	0.13935	0.102025	0.117995	0.075398	0.127011724	0.031888	0.068804	0.076212
5) Capital Cost										
H.E.L	0.380325	0.457677	0.281863	0.260113	0.393343	0.399028	0.264666655	0.044718	0.264155	0.297578
Prpg.Thermo	0.197313	0.054193	0.394479	0.330288	0.256611	0.232038	0.310626839	0.412161	0.238929	0.269161
VFD	0.169951	0.052531	0.075514	0.071198	0.15374	0.169873	0.09872184	0.183807	0.110819	0.124841
RC	0.08465	0.1452	0.031253	0.030267	0.029499	0.029095	0.042368755	0.047136	0.045966	0.051782
TOU	0.124044	0.1452	0.141375	0.199961	0.091129	0.09465	0.133600651	0.18704	0.134911	0.151982
P.F	0.043717	0.1452	0.075514	0.108174	0.075679	0.075317	0.15001526	0.125138	0.092901	0.104656

The overall priority For FAHP all Academic Experts

	RC	EI	IE	CA	CC		FAHP Result
H.E.L	0.170801	0.249409	0.176229	0.331603	0.297578	0.287008	0.238915145
Prpg.Thermo	0.418639	0.302273	0.409009	0.224079	0.269161	0.235998	0.331507959
VFD	0.136714	0.138642	0.144925	0.158485	0.124841	0.134827	0.139604864
RC	0.109683	0.062125	0.117934	0.062864	0.051782	0.160242	0.081535755
TOU	0.092977	0.17497	0.083718	0.146756	0.151982	0.181924	0.130430994
P.F	0.071187	0.072582	0.068184	0.076212	0.104656		0.078005283

Combination the judgments of all eight participants by using the geometric mean

New School Building - Academics

GM = Geometric mean

Numbers 1 to 8= the Participants in filling the questionnaire

Among Objectives	1	2	3	4	5	6	7	8	GM	NGM
Reduction	0.335081	0.260412	0.260412	0.322255	0.259509	0.297942	0.147977333	0.083775	0.226873	0.27007
Implement	0.247167	0.260412	0.260412	0.169511	0.176161	0.198708	0.366214598	0.083775	0.204437	0.243362
Impact	0.131778	0.260412	0.260412	0.322255	0.058302	0.056453	0.147977333	0.083775	0.136068	0.161975
Comfort	0.070951	0.070589	0.070589	0.052263	0.447727	0.39381	0.058849164	0.246937	0.121453	0.144577
Cost	0.215023	0.148175	0.148175	0.133717	0.058302	0.053087	0.278981572	0.501738	0.151223	0.180016
1) Reduction Criteria										
H.E.L	0.073349	0.060969	0.060969	0.09904	0.165116	0.138494	0.037477469	0.092063	0.082426	0.088934
H.E.AC	0.387994	0.235492	0.235492	0.303641	0.236324	0.291551	0.168225406	0.346699	0.267547	0.288674
BMS	0.269572	0.332148	0.332148	0.376171	0.206453	0.267817	0.371010526	0.245899	0.294402	0.31765
VFD	0.033746	0.058981	0.058981	0.100008	0.277661	0.029002	0.091789002	0.027241	0.062619	0.067563
PGT	0.11767	0.188804	0.188804	0.058032	0.082136	0.069249	0.091789002	0.172936	0.110344	0.119057
RC	0.11767	0.123606	0.123606	0.063109	0.03231	0.203887	0.239708595	0.115162	0.109476	0.118121
2) Ease Implementation										
H.E.L	0.320114	0.339	0.339	0.364781	0.368812	0.351284	0.241118281	0.399903	0.337325	0.356497
H.E.AC	0.232909	0.215545	0.215545	0.208706	0.09271	0.25521	0.259880253	0.028142	0.158123	0.16711
BMS	0.094377	0.141279	0.141279	0.088333	0.083498	0.145805	0.06667518	0.084001	0.101591	0.107365
VFD	0.100481	0.085823	0.085823	0.150003	0.204389	0.047581	0.14798541	0.187631	0.11471	0.12123
PGT	0.21496	0.179418	0.179418	0.145401	0.218219	0.159136	0.200977171	0.232409	0.189056	0.199801
RC	0.037158	0.038935	0.038935	0.042777	0.032373	0.040984	0.083363705	0.067913	0.045416	0.047997

3) Environment Impact										
H.E.L	0.073349	0.060969	0.060969	0.09904	0.077444	0.128678	0.037477469	0.102317	0.075284	0.079893
H.E.AC	0.387994	0.235492	0.235492	0.303641	0.26269	0.316139	0.168225406	0.379096	0.276941	0.293894
BMS	0.269572	0.332148	0.332148	0.376171	0.351778	0.210669	0.371010526	0.198492	0.297314	0.315514
VFD	0.033746	0.058981	0.058981	0.100008	0.078283	0.036467	0.091789002	0.035436	0.056844	0.060324
PGT	0.11767	0.188804	0.188804	0.058032	0.199961	0.084768	0.091789002	0.163198	0.125568	0.133255
RC	0.11767	0.123606	0.123606	0.063109	0.029844	0.223278	0.239708595	0.121461	0.110365	0.117121
4) Comfort ability to users										
H.E.L	0.370028	0.384647	0.384647	0.397322	0.337055	0.388725	0.328003703	0.371717	0.369502	0.383685
H.E.AC	0.206836	0.21966	0.21966	0.205816	0.192766	0.115746	0.193172601	0.07563	0.169131	0.175623
BMS	0.10725	0.067076	0.067076	0.11272	0.135843	0.084126	0.047659806	0.127405	0.088533	0.091931
VFD	0.086585	0.067076	0.067076	0.09046	0.084119	0.149392	0.114865068	0.155936	0.097146	0.100874
PGT	0.191924	0.194464	0.194464	0.152274	0.21483	0.229675	0.114865068	0.236084	0.18674	0.193907
RC	0.037377	0.067076	0.067076	0.041408	0.035387	0.032336	0.201433754	0.033228	0.051985	0.05398
5) Capital Cost										
H.E.L	0.370307	0.252026	0.252026	0.334702	0.378138	0.376906	0.264396407	0.375819	0.320556	0.332226
H.E.AC	0.10569	0.252026	0.252026	0.136305	0.143217	0.098133	0.264396407	0.097239	0.154852	0.16049
BMS	0.085011	0.130005	0.130005	0.087033	0.06705	0.064753	0.061611115	0.037411	0.077121	0.079929
VFD	0.206991	0.103973	0.103973	0.206972	0.143217	0.199373	0.18200254	0.134569	0.154454	0.160076
PGT	0.192067	0.217256	0.217256	0.190944	0.236329	0.233357	0.163996646	0.317551	0.217301	0.225212
RC	0.039935	0.044713	0.044713	0.044044	0.032049	0.027478	0.063596884	0.037411	0.04059	0.042068

The overall priority For FAHP all Academic Experts

	RC	EI	IE	CA	CC		FAHP Result
H.E.L	0.088934	0.356497	0.079893	0.383685	0.332226	0.27007	0.238995004
H.E.AC	0.288674	0.16711	0.293894	0.175623	0.16049	0.243362	0.22051563
BMS	0.31765	0.107365	0.315514	0.091931	0.079929	0.161975	0.190701205
VFD	0.067563	0.12123	0.060324	0.100874	0.160076	0.144577	0.100920902
PGT	0.119057	0.199801	0.133255	0.193907	0.225212	0.180016	0.170937925
RC	0.118121	0.047997	0.117121	0.05398	0.042068		0.077929334

Combination the judgments of all eight participants by using the geometric mean

New Religion Building - Academics

GM = Geometric mean

Numbers 1 to 8= the Participants in filling the questionnaire

Among Objectives	1	2	3	4	5	6	7	8	GM	NGM
Reduction	0.448818	0.421101	0.344201	0.322255	0.291749	0.213763	0.27916678	0.292379	0.318807	0.357918
Implement	0.198871	0.194079	0.151243	0.169511	0.120372	0.130348	0.25439117	0.1368	0.164657	0.184857
Impact	0.094531	0.053257	0.293129	0.322255	0.183475	0.213763	0.13743347	0.292379	0.171532	0.192575
Comfort	0.058908	0.114869	0.060185	0.052263	0.354851	0.384272	0.0498418	0.214648	0.115215	0.12935
Cost	0.198871	0.216693	0.151243	0.133717	0.049553	0.057854	0.27916678	0.063794	0.120515	0.1353
1) Reduction Criteria										
H.E.L	0.118492	0.118492	0.129993	0.124658	0.206317	0.103669	0.095844448	0.115097	0.123375	0.129149
H.E.AC	0.301057	0.301057	0.262827	0.262293	0.324024	0.256296	0.30939792	0.296462	0.288201	0.301687
BMS	0.301057	0.301057	0.361724	0.419797	0.249635	0.383772	0.173383122	0.296462	0.30122	0.315316
VFD	0.16393	0.077985	0.037478	0.083802	0.095548	0.066559	0.047510832	0.075216	0.074136	0.077605
TOC	0.037478	0.037478	0.129993	0.054725	0.041818	0.032257	0.162765031	0.040982	0.055491	0.058088
RC	0.077985	0.16393	0.077985	0.054725	0.082658	0.157446	0.211098647	0.175781	0.112874	0.118155
2) Ease Implementation										
H.E.L	0.345327	0.345327	0.217706	0.3439	0.34424	0.438647	0.363582167	0.350234	0.338328	0.362129
H.E.AC	0.14883	0.14883	0.255768	0.211854	0.115141	0.050205	0.192566121	0.077132	0.133854	0.143271
BMS	0.03387	0.03387	0.220373	0.08764	0.071879	0.050205	0.047256815	0.059056	0.062169	0.066542
VFD	0.23677	0.23677	0.100383	0.174206	0.183818	0.135565	0.07228696	0.205228	0.156639	0.167659
TOC	0.127094	0.127094	0.160378	0.147216	0.250147	0.14506	0.184382447	0.240462	0.167295	0.179064
RC	0.108109	0.108109	0.045392	0.035184	0.034775	0.180318	0.139925489	0.067887	0.07599	0.081336

3) Environment Impact										
H.E.L	0.118492	0.118492	0.129993	0.124658	0.347653	0.166736	0.095844448	0.115097	0.13975	0.152657
H.E.AC	0.301057	0.301057	0.262827	0.262293	0.224633	0.341417	0.30939792	0.296462	0.285348	0.311703
BMS	0.301057	0.301057	0.361724	0.419797	0.081351	0.254897	0.173383122	0.296462	0.248773	0.271749
VFD	0.16393	0.16393	0.037478	0.083802	0.185671	0.049696	0.047510832	0.075216	0.085225	0.093096
TOC	0.037478	0.037478	0.129993	0.054725	0.130325	0.045518	0.162765031	0.040982	0.066777	0.072945
RC	0.077985	0.077985	0.077985	0.054725	0.030367	0.141736	0.211098647	0.175781	0.089577	0.09785
4) Comfort ability to users										
H.E.L	0.339	0.339	0.357635	0.333339	0.34691	0.347582	0.338487709	0.377164	0.347144	0.362106
H.E.AC	0.141279	0.141279	0.166806	0.23433	0.14634	0.144258	0.19640618	0.126197	0.158988	0.165841
BMS	0.085823	0.085823	0.166806	0.080694	0.044574	0.044197	0.089848903	0.049371	0.073657	0.076832
VFD	0.253683	0.253683	0.142637	0.19367	0.185158	0.155053	0.04450872	0.169379	0.157816	0.164618
TOC	0.141279	0.141279	0.11903	0.123836	0.237995	0.266547	0.188044335	0.226848	0.172832	0.180282
RC	0.038935	0.038935	0.047086	0.034131	0.039023	0.042363	0.142704152	0.05104	0.048242	0.050321
5) Capital Cost										
H.E.L	0.344763	0.344763	0.338682	0.378824	0.407751	0.396311	0.359647355	0.426182	0.373376	0.388344
H.E.AC	0.209611	0.209611	0.168225	0.149609	0.108741	0.187144	0.182317055	0.074927	0.153449	0.1596
BMS	0.087763	0.087763	0.124118	0.081159	0.05571	0.120771	0.046737558	0.039988	0.074759	0.077755
VFD	0.209611	0.209611	0.082544	0.226585	0.183294	0.118101	0.087137211	0.181765	0.151786	0.157871
TOC	0.112942	0.112942	0.248953	0.130811	0.207624	0.140276	0.190372075	0.225959	0.163887	0.170457
RC	0.03531	0.03531	0.037477	0.033012	0.036879	0.037398	0.133788747	0.051178	0.0442	0.045972

The overall priority For FAHP all Academic Experts

	RC	EI	IE	CA	CC		FAHP Result
H.E.L	0.129149	0.362129	0.152657	0.362106	0.388344	0.357918	0.241945976
H.E.AC	0.301687	0.143271	0.311703	0.165841	0.1596	0.184857	0.237535479
BMS	0.315316	0.066542	0.271749	0.076832	0.077755	0.192575	0.197948648
VFD	0.077605	0.167659	0.093096	0.164618	0.157871	0.12935	0.119350415
TOC	0.058088	0.179064	0.072945	0.180282	0.170457	0.1353	0.114321626
RC	0.118155	0.081336	0.09785	0.050321	0.045972		0.088897857

Combination the judgments of all eight participants by using the geometric mean

Existing Religion Building - Academics

GM = Geometric mean

Numbers 1 to 8= the Participants in filling the questionnaire

Among Objectives	1	2	3	4	5	6	7	8	GM	NGM
Reduction	0.448818	0.421101	0.344201	0.322255	0.213763	0.251549	0.27916678	0.292379	0.312953	0.352018
Implement	0.198871	0.194079	0.151243	0.169511	0.130348	0.124728	0.25439117	0.1368	0.16539	0.186035
Impact	0.094531	0.053257	0.293129	0.322255	0.213763	0.204581	0.13743347	0.292379	0.173882	0.195587
Comfort	0.058908	0.114869	0.060185	0.052263	0.384272	0.367727	0.0498418	0.214648	0.115729	0.130175
Cost	0.198871	0.216693	0.151243	0.133717	0.057854	0.051416	0.27916678	0.063794	0.121072	0.136185
1) Reduction Criteria										
H.E.L	0.110556	0.087083	0.152151	0.250264	0.374998	0.173289	0.181837939	0.370028	0.188631	0.211166
Prpg.Thermo	0.200754	0.26737	0.312123	0.324752	0.238226	0.351234	0.311433051	0.174484	0.265565	0.29729
VFD	0.056553	0.26737	0.045853	0.039053	0.063322	0.094512	0.031272027	0.03574	0.060568	0.067804
RC	0.188689	0.031342	0.245296	0.175775	0.100597	0.246881	0.311433051	0.086585	0.142577	0.15961
TOU	0.200754	0.15901	0.152151	0.093358	0.039881	0.039572	0.082011965	0.126327	0.096329	0.107836
P.F	0.242693	0.187825	0.092426	0.116799	0.182976	0.094512	0.082011965	0.206836	0.139614	0.156293
2) Ease Implementation										
H.E.L	0.371592	0.089676	0.325001	0.342416	0.204275	0.337691	0.324935841	0.350415	0.271042	0.307836
Prpg.Thermo	0.149674	0.253657	0.219039	0.240767	0.129889	0.246778	0.167544581	0.142447	0.187563	0.213024
VFD	0.193073	0.169164	0.07007	0.082912	0.037383	0.15384	0.047284513	0.188677	0.099665	0.113195
RC	0.028204	0.02565	0.059089	0.037602	0.159059	0.029139	0.09828407	0.030568	0.046638	0.052969
TOU	0.094705	0.29269	0.219039	0.127256	0.078791	0.129567	0.156944912	0.209974	0.150265	0.170663
P.F	0.162752	0.169164	0.107762	0.169047	0.073659	0.102984	0.205006084	0.077919	0.125304	0.142314

3) Environment Impact										
H.E.L	0.110556	0.087083	0.156177	0.250264	0.274022	0.196937	0.181837939	0.370028	0.184904	0.204893
Prpg.Thermo	0.200754	0.26737	0.320489	0.324752	0.28607	0.352874	0.311433051	0.174484	0.272769	0.302257
VFD	0.056553	0.26737	0.047086	0.039053	0.066216	0.040618	0.031272027	0.03574	0.054987	0.060932
RC	0.188689	0.031342	0.251728	0.175775	0.128846	0.25028	0.311433051	0.086585	0.147786	0.163763
TOU	0.200754	0.15901	0.11903	0.093358	0.043412	0.037069	0.082011965	0.126327	0.093645	0.103769
P.F	0.242693	0.187825	0.10549	0.116799	0.201434	0.122221	0.082011965	0.206836	0.148348	0.164385
4) Comfort ability to users										
H.E.L	0.409849	0.317579	0.322717	0.356372	0.327175	0.410068	0.27870945	0.308594	0.338588	0.363582
Prpg.Thermo	0.092833	0.372305	0.322717	0.204063	0.264123	0.178821	0.27870945	0.294926	0.233499	0.250735
VFD	0.181304	0.052612	0.059768	0.180584	0.172406	0.044564	0.04301	0.17802	0.093924	0.100857
RC	0.040896	0.052612	0.093256	0.042791	0.070515	0.078544	0.095269507	0.071422	0.065125	0.069932
TOU	0.093813	0.053134	0.141775	0.129863	0.138019	0.126856	0.152150797	0.115188	0.113817	0.122218
P.F	0.181304	0.151759	0.059768	0.086327	0.027761	0.161148	0.152150797	0.03185	0.086303	0.092674
5) Capital Cost										
H.E.L	0.326191	0.084376	0.296953	0.362513	0.311926	0.307833	0.356834759	0.331959	0.276028	0.2929
Prpg.Thermo	0.091122	0.263108	0.281851	0.23433	0.311926	0.266672	0.206663273	0.247895	0.225759	0.239559
VFD	0.18116	0.263108	0.128044	0.080694	0.114149	0.110599	0.057461919	0.168004	0.125109	0.132757
RC	0.039208	0.02206	0.037873	0.036613	0.032129	0.035482	0.057461919	0.035524	0.035952	0.038149
TOU	0.153035	0.183674	0.174399	0.164496	0.152365	0.19601	0.160789065	0.137856	0.164408	0.174458
P.F	0.209284	0.183674	0.08088	0.121354	0.077504	0.083404	0.160789065	0.078762	0.115138	0.122176

The overall priority For FAHP all Academic Experts

	RC	EI	IE	CA	CC		FAHP Result
H.E.L	0.211166	0.307836	0.204893	0.363582	0.2929	0.352018	0.258894959
Prpg.Thermo	0.29729	0.213024	0.302257	0.250735	0.239559	0.186035	0.268662864
VFD	0.067804	0.113195	0.060932	0.100857	0.132757	0.195587	0.088052407
RC	0.15961	0.052969	0.163763	0.069932	0.038149	0.130175	0.112368522
TOU	0.107836	0.170663	0.103769	0.122218	0.174458	0.136185	0.12967393
P.F	0.156293	0.142314	0.164385	0.092674	0.122176		0.142347318